LWG
LOWER WILLAMETTE GROUP

PORTLAND HARBOR RI/FS

RISK MANAGEMENT RECOMMENDATIONS

CONTAMINANTS OF CONCERN, RECEPTORS, PATHWAYS, AND BENTHIC AREAS OF CONCERN FOR THE FEASIBILITY STUDY

FINAL

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

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Prepared for
The Lower Willamette Group

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

LIST OF ACRONYMS

AOC	area of concern
BEHP	bis(2-ethylhexyl) phthalate
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
CERCLA	Comprehensive Environmental Recovery, Compensation and Liability Act
COC	contaminant of concern
COPC	contaminant of potential concern
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
ERAGS	Ecological Risk Assessment Guidance for Superfund
FS	Feasibility Study
HI	hazard index
HQ	hazard quotient
LOE	line of evidence
LWG	Lower Willamette Group
MCPP	2-(2-Methyl-4-chlorophenoxy)propionic acid
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
RI	Remedial Investigation
RM	river mile
SLERA	Screening Level Ecological Risk Assessment
Total DDx	sum of all six DDT isomers (2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT and 4,4'-DDT)
TRV	toxicity reference value
TZW	transition zone water
VOC	volatile organic compound
W	west

ES. EXECUTIVE SUMMARY

The baseline human health and ecological risk assessments for Portland Harbor found that exposure to contaminants was posing potentially unacceptable risks to human health and ecological resources. The baseline risk assessments focused on the approximate 10-mile portion of the Lower Willamette River from river mile (RM) 1.9 to RM 11.8, which is referred to as the Study Area. The purpose of this document is to provide recommendations to risk managers for use in developing and evaluating sediment remedial alternatives that are protective of human health and ecological resources, once ongoing sources of contamination are controlled.

This document recommends contaminants of concern (COCs), receptors, exposure pathways, and benthic areas of concern (AOCs) that should be used in the feasibility study (FS) to develop and evaluate sediment remedial alternatives. The identification of COCs is not intended to suggest that other contaminants, receptors, and exposure pathways identified in the baseline risk assessments do not also pose potentially unacceptable risks. All contaminants identified through the baseline risk assessments as posing potentially unacceptable risk will be considered in the FS, but the COCs, exposure pathways, receptors, and AOCs recommended in this document are sufficient to assess the protectiveness of potential sediment remedies.

The risk management recommendations presented in this report are limited in scope to recommendations about COCs, exposure pathways, receptors, and AOCs. Other risk management considerations should be addressed in the FS, beyond what is presented in this report, including uncertainty in risk assessment assumptions and conclusions, and considerations that are not related to the baseline risk assessments.

Sensitivity analyses should be used to critically examine the effect of risk management considerations in the FS. It is recommended that the sensitivity of risk results to key unknowns and assumptions be thoroughly evaluated and understood as part of the FS.

ES-1. HUMAN HEALTH RISK MANAGEMENT RECOMMENDATIONS

U.S. Environmental Protection Agency (EPA) guidance (EPA 1991, 2005) identifies the cancer risk range of 1×10^{-6} to 1×10^{-4} as the "target range" within which risks should be considered and managed during the FS process. Furthermore, if the cumulative cancer risk to an individual based on reasonable maximum exposure (RME) assumptions is less than 1×10^{-4} and the non-cancer hazard quotient (HQ) is less than 1, remedial action is not warranted at a site (EPA 1991). EPA has a preference to select remedies that are at the more protective end of the risk range; EPA also recognizes that site-specific information and analyses will be considered in the FS in order to make a final determination of protectiveness. Oregon Department of Environmental Quality (DEQ) guidance sets an acceptable cancer risk level of 1 x 10^{-6} for individual chemicals and 1 x 10^{-5} for cumulative cancer risks (OAR 340-122-0115).

Consistent with EPA and DEQ guidance, contaminants were identified as potentially posing unacceptable risks[1] if they resulted in a cancer risk greater than 1 x 10^{-6} or an HQ greater than 1 under any of the exposure scenarios evaluated in the baseline human health risk assessment (BHHRA). Therefore, risk management recommendations flowing from the BHHRA address contaminants and exposure pathways exceeding a cancer risk of 1 x 10^{-6} or HQ greater than 1. Based on the results of the BHHRA, applying the risk management approach discussed below, the only exposure pathways that should be used in the FS to develop and evaluate remedial alternatives protective of human health are:

- Consumption of fish
- Consumption of clams (from beach areas in shallow water only)
- Exposure to in-water sediments (at RM 7 west (W) and RM 6W only)

Based on the results of the BHHRA, the COCs that should be considered in the FS to develop and select remedy options protective of human health are:

- For the fish consumption exposure pathway: polychlorinated biphenyls (PCBs),dioxins/furans, and total DDx (the sum of the six DDT congeners)
- For the shellfish consumption exposure pathway: PCBs, dioxins/furans, and carcinogenic polycyclic aromatic hydrocarbon (PAHs).
- For the in-water sediment exposure pathway: dioxins/furans (RM 7W) and carcinogenic PAHs (RM 6W)

The BHHRA intentionally incorporated conservative assumptions, consistent with EPA guidance, to provide a health protective estimate of risks. Uncertainties related to the risk assessment assumptions will be evaluated in the FS.

ES-2. ECOLOGICAL RISK MANAGEMENT RECOMMENDATIONS

Consistent with EPA guidance (EPA 1997, 1998, 2005), the baseline ecological risk assessment (BERA) reported potentially unacceptable ecological risks based on an iterative process of analyzing exposure and effects data for contaminants in

[1] In the BHHRA, all chemicals found to pose cancer risks greater than 1 x 10^{-6} or HQs greater than 1 at the end of the risk characterization were identified as contaminants potentially posing unacceptable risks. In the BERA, all chemicals with HQs greater than or equal to 1.0 at the end of the risk characterization were identified as contaminants posing potentially unacceptable risks. The BERA term "posing potentially unacceptable risk" and the BHHRA term "potentially posing unacceptable risk" are used synonymously.

sediments and surface water and different ecological receptors. Several lines of evidence (LOEs) were evaluated. For each LOE, risk characterization began with a screening level ecological risk assessment (SLERA) and progressed iteratively with closer examination of site-specific and ecotoxicity data at each step. Throughout the process, chemical-receptor pairs that showed the potential for adverse effects were further analyzed and those that did not were screened out. Exposure data in the final step of the risk analysis were evaluated at the scale over which the receptors are likely to be directly exposed and, where pertinent, potentially contaminated prey were likely to be consumed. For the least mobile receptors (e.g., benthic macroinvertebrates, sculpin, and aquatic plants), exposure areas were conservatively evaluated over areas no larger than the immediate area where samples were collected; for the most mobile receptors (e.g., white sturgeon and largescale sucker), exposure areas encompassed the entire Study Area. For moderately mobile receptors (e.g., smallmouth bass and mink) the Study Area was divided into 1 to 3 mile exposure areas.

Numerical risk estimates in the BERA were calculated as HQs. HQs were calculated separately for each chemical-receptor pair for each exposure area. Chemical-receptor pairs resulting in HQ greater than or equal to 1 in any exposure area were identified as posing potentially unacceptable risk. In sediments, a location was identified as posing potentially unacceptable risk to benthic invertebrates if the sediment was toxic or predicted to be toxic based on a sediment COC concentration that exceeded a site-specific sediment quality value (SQV).

Therefore, risk management recommendations flowing from the BERA address chemicals, ecological receptors, and exposure pathways that exceed an HQ of 1 or (in the case of benthic invertebrates in sediments) a site-specific SQV. Based on the results of the BERA, applying the risk management approach discussed below, the only COCs, receptors and benthic AOCs that should be used in assessing the protectiveness of potential remedies to ecological resources in the FS are:

- PCBs and dioxins/furans are the recommended COCs for assessing risk to ecological receptors except benthic organisms (including fish). Mink is the recommended receptor of concern.

- 4,4′-DDT, total DDx, chlorobenzene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and trichloroethene are the recommended transition zone water (TZW) COCs[2]. These recommendations presume that groundwater source control measures will be implemented prior to sediment remedies. DEQ is

[2] The risk from contaminants in TZW may be lower than indicated by the maximum concentrations in unfiltered samples because of the lower bioavailability of the particulate-bound fraction of the contaminant.

working with upland property owners to implement groundwater source control measures prior to sediment remedies.

- Recommended benthic AOCs were identified by applying the comprehensive benthic approach required by EPA to assess benthic risk in the FS (EPA 2010). Benthic risks were identified based on the spatial extent and magnitude of measured or predicted toxicity of contaminant mixtures in sediment. Eighteen discrete areas representing approximately 7 percent of the Study Area were associated with deleterious effects on benthic organisms.

Special approaches are needed in the FS process to develop and evaluate remedies for protection of species potentially impacted by TZW and for protection of benthos potentially impacted by chemicals in sediment. For TZW exposures, remedies should be evaluated in the FS based on the degree to which they protect benthic invertebrate communities and Pacific lamprey ammocoetes from chemicals in groundwater discharge, assuming that groundwater source control measures have been implemented. For protection of benthos exposed to chemicals in sediment, remedies in the FS should be evaluated based on predicted toxicity metrics and should take into account changes in sediment quality due to sedimentation and chemical degradation that occur prior to implementation of the remedies.

1.0 INTRODUCTION

The baseline human health risk assessment (BHHRA) and baseline ecological risk assessment (BERA) were conducted as part of the Portland Harbor remedial investigation/feasibility study (RI/FS). The BHHRA and BERA were conducted in accordance with technical guidance and other requirements set forth by the U.S. Environmental Protection Agency (EPA) and the Oregon Department of Environmental Quality (DEQ), and were focused on the approximate 10-mile portion of Portland Harbor from river mile (RM) 1.9 to RM 11.8, which is referred to as the Study Area. The BHHRA and BERA identified contaminants posing potentially unacceptable risks to human health and ecological receptors. The BERA also identified the areas posing potentially unacceptable risk to the benthic community. The results of the BHHRA and BERA will be used to develop remedial action objectives and assist in risk management decisions (EPA 1988, 2005).

In accordance with guidance from EPA (1989), which is consistent with DEQ guidance (2010), the BHHRA incorporated the four steps of the baseline risk assessment process: data collection and evaluation, exposure assessment, toxicity assessment, and risk characterization. The BHHRA provided quantitative estimates of risk and the related uncertainties. The BHHRA also identified those exposure scenarios and contaminants that were the primary contributors to overall risks, consistent with EPA guidance (1989).

Risk estimates in the BERA were calculated to be consistent with Comprehensive Environmental Recovery, Compensation and Liability Act (CERCLA) guidance (EPA 1997, 1998) and EPA's Problem Formulation (see BERA Attachment 2). In accordance with EPA's Ecological Risk Assessment Guidance for Superfund (ERAGS) (EPA 1997), the risk conclusions in the BERA identified the receptor-contaminant pairs that are reasonably likely to result in adverse effects on the assessment endpoints selected to represent the valued ecological attributes of the Study Area.

Consistent with agreements between EPA Region 10 and the Lower Willamette Group (LWG), contaminants found to pose cancer risks greater than 1×10^{-6} or hazard quotients (HQs) greater than 1 were identified as contaminants potentially posing unacceptable risks in the BHHRA. In the BERA, contaminants with HQs greater than or equal to one at the end of the risk characterization were identified as contaminants posing potentially unacceptable risks[3]. Contaminants identified as posing potentially unacceptable risks in the BHHRA and BERA will be carried forward into the FS.

[3] The BERA term "posing potentially unacceptable risk" and the BHHRA term "potentially posing unacceptable risk" are used synonymously.

Risk management recommendations for all the contaminants posing potentially unacceptable risks are presented in detail in Attachments 1 and 2 to this document. A subset of the contaminants posing potentially unacceptable risks is recommended for purposes of developing and evaluating remedial alternatives in the FS. The contaminants that are recommended for this purpose are referred to as contaminants of concern (COCs). The identification of COCs is not intended to suggest that other contaminants identified in the baseline risk assessments do not also pose potentially unacceptable risks. All contaminants identified through the baseline risk assessments as posing potentially unacceptable risk will be considered in the FS, but the COCs, exposure pathways, receptors, and AOCs recommended in this document are sufficient to assess the protectiveness of potential sediment remedies.

This document recommends the COCs, exposure pathways, receptors, and areas of concern (AOCs) that should be used in the FS to develop and evaluate remedial alternatives that are protective of human health and ecological resources. The BHHRA risk management recommendations presented in this report are based on:

- The uncertainties in the risk estimates
- The magnitude and geographic scale of the risks
- Contributions to overall risks

The BERA recommendations took into account the following factors:

- How often, where, and in which media risk thresholds were exceeded
- The ecological relevance (strengths and weaknesses) of the exposure estimates used to calculate HQs
- The toxicological effects associated with the toxicity reference value (TRV)
- The magnitude of the exceedance
- Whether a relationship was found between contaminant concentrations in co-located sediment and tissue samples (for small-home-range species)
- The relative strength and concordance among lines of evidence (LOEs) used to evaluate risks
- Comparison of Study Area concentrations with available background or upriver data

The risk management recommendations presented in this report are limited in scope to recommendations about COCs, exposure pathways, receptors, and AOCs. Other risk management considerations should be addressed in the FS, beyond what is presented in this report, including uncertainty in risk assessment assumptions and conclusions and considerations that are not related to the baseline risk assessments.

The remainder of this document is organized in three sections, as follows:

- **Section 2. Human Health Risk Management Recommendations** – A description of risk management recommendations based on the results of the BHHRA
- **Section 3. Ecological Risk Management Recommendations** – A description of risk management recommendations based on the results of the BERA
- **Section 4. Conclusions** – A summary of risk management recommendations regarding contaminants and exposure pathways to be carried forward into the FS

2.0 HUMAN HEALTH RISK MANAGEMENT RECOMMENDATIONS

This section provides a brief summary of the conclusions from the BHHRA (Kennedy/Jenks, 2011), and provides risk management recommendations to be carried forward to the FS.

A summary of the risks for each of the media evaluated in the BHHRA (fish tissue, shellfish tissue, in-water sediment, beach sediment, surface water, and groundwater seeps) is presented in Attachment 1. Attachment 1 includes the risks for the exposure scenarios evaluated in the BHHRA, identifies the contaminants potentially posing unacceptable risks for those scenarios, and presents the uncertainties associated with the scenarios recommended for use in the FS to develop and evaluate remedial alternatives protective of human health. Attachment 1 also details the rationale for recommending or not recommending contaminants as COCs.

2.1 SUMMARY OF BASELINE HUMAN HEALTH RISK ASSESSMENT

The overall objective of the BHHRA was to evaluate whether exposure to contaminants in sediment, surface water, groundwater seeps, or biota (fish or shellfish) may result in unacceptable risks to human health. The exposure scenarios evaluated in the BHHRA incorporated the ingestion and dermal absorption pathways from a number of different exposure areas by workers, transients, beach users, fishers, divers, and residents. In addition, exposures from fish and shellfish consumption were evaluated for a number of different tissue types, species consumed, and ingestion rates, resulting in a multiple scenarios for the same exposure pathway and medium.

Contaminants were identified as potentially posing unacceptable risks if they resulted in a cancer risk greater than 1×10^{-6} or an HQ greater than 1 under any of the BHHRA exposure scenarios, which encompass ranges of exposure assumptions at multiple exposure areas with ranges of exposure point concentrations, regardless of the uncertainties. The following summarizes the contaminants potentially posing unacceptable risk by exposure pathway:

- *Fish consumption.* The contaminants potentially posing unacceptable risks for at least one of the fish consumption scenarios were: polychlorinated biphenyls (PCBs), dioxins/furans, six metals (antimony, arsenic, lead, mercury, selenium, and zinc), bis 2-ethylhexyl phthalate (BEHP), polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene, seven pesticides (aldrin, dieldrin, heptachlor epoxide, total chlordane, total dichlorodiphenyldichloroethane [DDD], total dichlorodiphenyldichloroethylene [DDE], total dichlorodiphenyltrichloroethane [DDT]), and polybrominated diphenyl ethers (PBDEs). Of these, PCBs resulted in the highest cancer risks and hazard quotients.

- *Shellfish consumption.* Shellfish consumption was evaluated using both crayfish and clam tissue data in the BHHRA. The contaminants potentially posing unacceptable risks for at least one of the crayfish consumption scenarios were: PCBs, dioxins/furans, arsenic, PAHs, pentachlorophenol, and total DDE. The contaminants potentially posing unacceptable risks for at least one of the clam consumption scenarios were: PCBs, dioxins/furans, arsenic, PAHs, and five pesticides (aldrin, dieldrin, total DDD, total DDE, and total DDT). Of these, PCBs resulted in the highest cancer risks and hazard quotients for both species.
- *Direct exposure to in-water sediment.* Four contaminants (PCBs, dioxins/furans, arsenic, and PAHs) were identified as potentially posing unacceptable risks for at least one of the in-water sediment scenarios.
- *Direct exposure to beach sediment*. Two contaminants (arsenic and PAHs) were identified as potentially posing unacceptable risks for at least one of the scenarios evaluated for direct contact with beach sediment.
- *Direct exposure to surface water*. Four contaminants were identified as potentially posing unacceptable risks for at least one of the surface water scenarios: 2-(2-Methyl-4-chlorophenoxy)propionic acid (MCPP), arsenic, hexavalent chromium, and PAHs.

Of the exposure pathways evaluated in the BHHRA, risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risks resulting from direct contact with sediment, surface water, or seeps. Risks from fish and shellfish consumption exceed the EPA point of departure for cancer risk of 1×10^{-6}, as well as the target cancer risk range of 1×10^{-6} to 1×10^{-4} and target hazard index (HI) of 1. For all species and consumers, PCBs are the primary risk contributor. With the exception of two ½-mile river segments for the tribal fisher scenario and one location for the hypothetical use of untreated surface water as a drinking water source by a future resident, all of the direct contact scenarios result in risks within or below the EPA target cancer risk range of 1×10^{-6} to 1×10^{-4}. The direct contact exposure pathways also result in non-cancer hazards below the target HI of 1, with the exception of one ½-river mile segment for in-water sediment and one location for hypothetical use of untreated surface water as a drinking water source.

2.2 HUMAN HEALTH RISK MANAGEMENT RECOMMENDATIONS SUMMARY

Based on the results of the BHHRA, only those exposure pathways and contaminants identified as potentially posing unacceptable risks were considered in the recommendations of COCs for use in the FS to develop and evaluate remedy options that are protective of human health. Additional considerations in the recommendations of COCs included:

- The relative percentage of each contaminant's contribution to the total human health risk consistent with assumptions on exposure areas.
- Frequency of cancer risks greater than 1×10^{-6} or hazard quotients greater than 1, both on a localized basis and Study Area-wide.
- Potential contributions from background concentrations to the cancer risks and noncancer hazards.
- Magnitude of risk exceedance above EPA's target range for managing cancer risk of 1×10^{-4} to 1×10^{-6} and noncancer hazard of one.

The recommended COCs based on the above criteria for the exposure pathways evaluated in the BHHRA are presented in Table 2-1. The rationale for recommending or not recommending the COCs is discussed in greater detail in Attachment 1.

The BHHRA intentionally incorporated conservative assumptions regarding potential frequency and magnitude of exposure, consistent with EPA guidance, to provide a health protective estimate of risks at Portland Harbor. However, it is not known with certainty which of the exposure scenarios evaluated in the BHHRA are actually occurring at the site, and for those scenarios which may exist, what are the actual exposures relative to the conservative exposures assumed using EPA guidance. These uncertainties and others will be considered in the FS.

For the fish consumption exposure pathway, PCBs, dioxins/furans, and total DDx are the contaminants recommended as COCs. PCBs and dioxins/furans are the primary contributors to cumulative risk estimates. Risks associated with total DDx are localized to RM 7, where it contributes only approximately 3% of the total risks.

As described, a number of assumptions used throughout the BHHRA are conservative in nature, and this is particularly true in the case of fish consumption. The EPA-directed fish ingestion rates, use of maximum concentrations in fish, type of fish species and fish tissue consumed, and assumed cooking and preparation methods for estimating risks from fish consumption will be considered in the FS as part of the remedy evaluations for protection of human health. The assumptions that individuals fish exclusively within one river mile in the Study Area for smallmouth bass (and do not obtain fish from any other sources), and that this fishing occurs over the entire duration of an individual's lifetime, also need to be more closely considered.

For the shellfish consumption exposure pathway, PCBs, dioxins/furans, and carcinogenic PAHs are recommended as COCs in the FS for clam consumption. Crayfish consumption is not a recommended pathway because evaluation of fish and clam consumption in the FS will address contaminants that may pose risk from crayfish consumption. Uncertainties arising from the assumptions about the shellfish species consumed, exposure duration, ingestion rates, spatial scale of exposure areas, and use of undepurated tissue in risk estimates should be considered in the FS in evaluating the risk reduction that can be realized from remedial alternatives.

For the in-water sediment exposure pathway, dioxins/furans and carcinogenic PAHs are recommended as COCs. Dioxins/furans were the primary contributor to risk in RM 7 west (W). Carcinogenic PAHs were the primary contributor to risk in RM 6W. The localized nature of risk exceedances from direct exposure to in-water sediment should be considered in the FS in evaluating remedies that would be protective of human health.

COCs are not recommended for any of the other exposure pathways evaluated in the BHHRA. For the beach sediment exposure pathway, no chemicals are recommended as COCs in the FS due to the low magnitude of risks and high degree of uncertainty in the exposure parameters for the beach sediment exposure scenarios. For the surface water pathway, no chemicals are recommended as COCs in the FS given the low magnitude of risks and high degree of uncertainty associated with the exposure assumptions used to evaluate the scenarios for direct contact with surface water. For the groundwater seep pathway, no chemicals are recommended as COCs because the BHHRA resulted in no chemicals potentially posing unacceptable risk for this pathway.

3.0 ECOLOGICAL RISK MANAGEMENT RECOMMENDATIONS

This section presents a summary of the ecological risk assessment (Section 3.1) and the LWG's ecological risk management recommendations (Section 3.2). The risk assessment summary is based on findings presented in Section 11 of the BERA. The risk management recommendations are based on Section 12 of the BERA (Windward 2011).

3.1 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

Exposure data in the BERA were evaluated at spatial scales over which selected ecological receptors were considered likely to be directly exposed and, where pertinent, potentially contaminated prey were likely to be consumed. For the least mobile receptors (e.g., benthic macroinvertebrates, sculpin, and aquatic plants), exposure was conservatively evaluated over areas no larger than the immediate area where samples were collected. For the most mobile receptors (e.g., white sturgeon and largescale sucker), the exposure areas encompass the entire Study Area. For moderately mobile receptors (e.g., smallmouth bass and mink) the Study Area is divided into several exposure areas each 1 to 3 miles long.

Risk conclusions were based on the spatial extent, magnitude of TRV exceedance, ecological significance of the TRV, and the concordance of different lines of evidence (e.g. for evaluation of fish, fish tissue concentration and water chemistry LOE were available). The main conclusions of the BERA by receptor group are summarized in detail in Attachment 2 and summarized briefly below. Complete risk conclusions can be found in the BERA. This summary is abridged to focus on those contaminants of potential concern (COPCs) and receptors for which the risk was concluded to be either low or significant. Negligible risk conclusions are not presented here but are presented in the BERA.

- PCBs were concluded to pose significant risk to mink, river otter, and spotted sandpiper, and low risk to osprey, bald eagle, sculpin and smallmouth bass.

- The combination of dioxin-like PCBs and dioxins/furans was found to pose significant risk to mink and river otter, and low risk to spotted sandpiper, osprey, and bald eagle.

- Sum DDE was found to pose low to negligible risk to bald eagle.

- Zinc, benzo(a)anthracene, benzo(a)pyrene, naphthalene, 4,4'-DDT, and the sum of all six DDT isomers (total DDx) were found to pose localized risk to individual Pacific lamprey ammocoetes due to potential exposure to contaminated shallow transition zone water (TZW).

- Benthic risks were identified based on the spatial extent and magnitude of measured or predicted toxicity of contaminant mixtures in sediment. Eighteen discrete areas representing approximately 7 percent of the Study Areas were associated with deleterious effects on benthic organisms. Additional benthic risks based on the surface water, TZW and tissue residue lines of evidence identified PAHs, PCBs and DDx as contaminants contributing to risk.

3.2 ECOLOGICAL RISK MANAGEMENT RECOMMENDATIONS SUMMARY

The purpose of the ecological risk management recommendations is to identify COCs, receptors, and AOCs that the LWG considers necessary and sufficient to develop and evaluate remedial alternatives protective of ecological resources. Attachment 2 provides a detailed discussion of the selection of COCs as well as why other COPCs were not designated as COCs.

In summary, the following are recommended as receptor-COC pairs of concern for further consideration in the FS:

- For non-benthic receptors, PCBs and dioxins/furans are the recommended COCs for assessing risk. Mink is the recommended receptor of concern. Most of the contaminants posing potentially unacceptable risk were not recommended as COCs for the non-benthic receptors based on risk characterization considerations (magnitude, spatial extent, and ecological significance of HQs greater than or equal to 1). This list includes all the metals, butyltin, phthalate, pesticide, and volatile organic compound (VOC) COPCs.

- For aquatic receptors exposed via TZW, 4,4′-DDT, total DDx, chlorobenzene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and trichloroethene are the recommended COCs.[4] These recommendations presume that groundwater source control measures will be implemented prior to sediment remedies. DEQ is working with upland property owners to implement groundwater source control measures prior to sediment remedies.

- For benthic receptors, recommended benthic AOCs were identified by applying the comprehensive benthic approach based on EPA's April 21, 2010 guidelines for assessing benthic risk in the FS (EPA 2010). The locations of AOCs where benthic risks need to be addressed in the FS work are presented in Map 3-1. The FS work should focus on the

[4] The risk from contaminants in TZW may be lower than indicated by the maximum concentrations in unfiltered samples because of the lower bioavailability of the particulate-bound fraction of the contaminant.

predicted toxicity metrics to evaluate potential remedies and should take into account sediment quality changes (due to deposition, chemical degradation, etc.) that will take place before active implementation of remedies.

4.0 CONCLUSIONS

This document recommends COCs, exposure pathways, receptors, and benthic AOCs that are sufficient to develop and evaluate remedial alternatives protective of human health and ecological resources. Sensitivity analyses should be used to critically examine the effect of risk management considerations in the FS. It is recommended that the sensitivity of risk results to key unknowns and assumptions be thoroughly evaluated and understood as part of the FS.

Based on the results of the BHHRA, the exposure pathways that should be used in the FS to develop and evaluate remedial alternatives protective of human health are:

- Consumption of fish
- Consumption of clams (from beach areas in shallow water only).
- Exposure to in-water sediments (at RM 7W and RM 6W only)

Based on the results of the BHHRA, the COCs that should be considered in the FS to develop and evaluate remedial alternatives protective of human health are:

- For the fish consumption exposure pathway: PCBs, dioxins/furans, and total DDx
- For the shellfish consumption exposure pathway: PCBs, dioxins/furans, and carcinogenic PAHs
- For the in-water sediment exposure pathway: dioxins/furans (RM 7W) and carcinogenic PAHs (RM 6W)

Based on the results of the BERA, the COCs, receptors and benthic AOCs that should be used in assessing the protectiveness of potential remedies to ecological resources in the FS are:

- PCBs and dioxins/furans are the recommended COCs for assessing risk to ecological receptors except benthic organisms (including fish). Mink is the recommended receptor of concern.
- 4,4′-DDT, total DDx, chlorobenzene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and trichloroethene are the recommended TZW COCs[5]. These recommendations presume that groundwater source control measures will be implemented prior to sediment remedies. DEQ is working with upland

[5] The risk from contaminants in TZW may be lower than indicated by the maximum concentrations in unfiltered samples because of the lower bioavailability of the particulate-bound fraction of the contaminant.

property owners to implement groundwater source control measures prior to sediment remedies.

- Recommended benthic AOCs were identified by applying the comprehensive benthic approach required by EPA to assess benthic risk in the FS (EPA 2010). Eighteen discrete areas representing approximately seven percent of the Study Area were associated with deleterious effects on benthic organisms. These AOCs, plus PCBs and dioxins/furans, will provide a sufficient basis for evaluating Portland Harbor remedial alternatives in the FS, subject to confirmation of protectiveness against other potentially unacceptable risks.

Special approaches are needed in the FS process to develop and evaluate remedies for protection of species potentially impacted by TZW and for protection of benthos potentially impacted by chemicals in sediment. For TZW exposures, remedies should be evaluated in the FS based on the degree to which they protect benthic invertebrate communities and Pacific lamprey ammocoetes from chemicals in groundwater discharge, assuming that groundwater source control measures have been implemented. For protection of benthos exposed to chemicals in sediment, remedies in the FS should be evaluated based on predicted toxicity metrics and should take into account changes in sediment quality due to sedimentation and chemical degradation that occur prior to implementation of the remedies.

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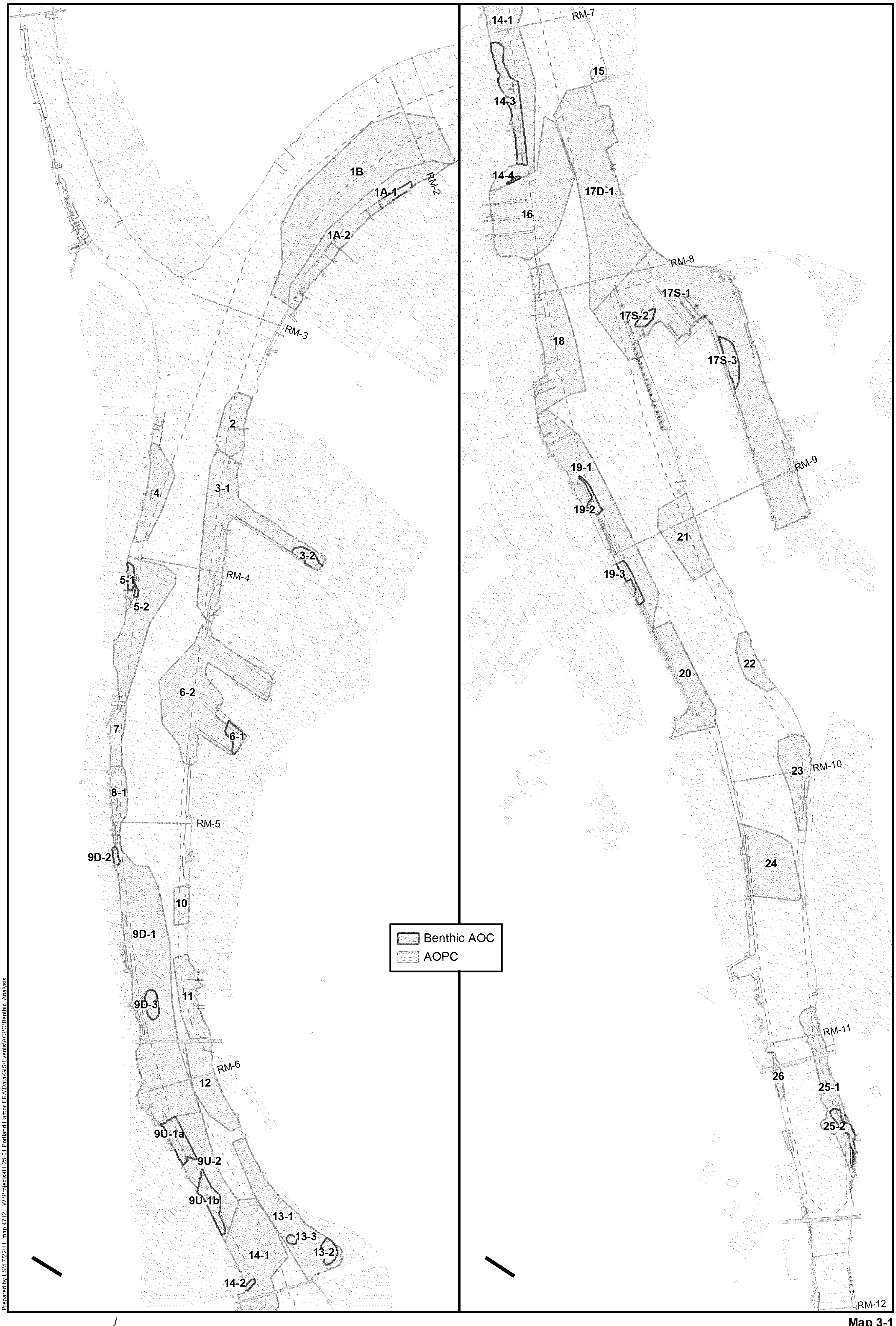
Table 2-1. Recommended Contaminants of Concern and Exposure Pathways for the Feasibility Study

	BHHRA Exposure Pathway						
Contaminant	In-Water Sediment, Direct Contact	Fish Consumption	Shellfish Consumption	Beach Sediment, Direct Contact	Groundwater Seep, Direct Contact	Surface Water, Direct Contact	Infant Consumption of Human Milk
Carcinogenic PAHs	X[a]		X				
PCBs		X	X				
Dioxins/furans	X[b]	X	X				
Total DDx		X[c]					

Notes:

a COC for river mile 6 west only
b COC for river mile 7 west only
c COC for river mile 7 only

X Contaminant/pathway is recommended as a COC in the FS.
BHHRA baseline human health risk assessment
DDD dichlorodiphenyldichloroethane
DDE dichlorodiphenyldichloroethylene
DDT dichlorodiphenyltrichloroethane
DDx sum of the six DDT congeners (2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT)
PCB polychlorinated biphenyl
PAH polycyclic aromatic hydrocarbon



Windward environmental LLC

LWG LOWER WILLAMETTE GROUP

0 1,000 2,000 3,000 Feet

FEATURE SOURCES:
Transportation, Property, or Boundaries: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.

Outfall information contained on this map is accurate according to available records; however, the City of Portland makes no warranty, expressed or implied, as to the completeness or accuracy of the information published.

P Outfall
P Dock
5 Roof
Bridge
Dock or Structure
Upland Site (2008)
River Mile
Navigation Channel
River or Slough

Map 3-1
Benthic Areas of Concern Recommended for Evaluation in the Feasibility Study
Portland Harbor RI/FS

FINAL
Recommended for Inclusion in Administrative Record

LOWER WILLAMETTE GROUP

PORTLAND HARBOR RI/FS

RISK MANAGEMENT RECOMMENDATIONS

ATTACHMENT 1: SUMMARY OF HUMAN HEALTH RISK ASSESSMENT AND RISK MANAGEMENT RECOMMENDATIONS

FINAL

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD

July 22, 2011

Prepared for
The Lower Willamette Group

Prepared by
Kennedy/Jenks Consultants

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ALM	Adult Lead Methodology
ATSDR	Agency for Toxic Substance and Disease Registry
BEHP	bis(2-ethylhexyl) phthalate
BHHRA	Baseline Human Health Risk Assessment
CERCLA	Comprehensive Environmental Recovery, Compensation and Liability Act
cm/hr	centimeters per hour
COC	contaminant of concern
CT	central tendency
CRITFC	Columbia River Inter-Tribal Fish Commission
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEHP	di(2-ethylhexyl) phthalate
DEQ	Oregon Department of Environmental Quality
DHS	Oregon Department of Health Services
E	east
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
EPD	effective predictive domain
FS	Feasibility Study
g/day	grams per day
HI	Hazard Index
HQ	hazard quotient
Kp	dermal permeability coefficient
LWG	Lower Willamette Group
MCPP	2-(2-Methyl-4-chlorophenoxy)propionic acid
µg/kg	micrograms per kilogram
mg/kg	milligrams per kilogram
OAR	Oregon Administrative Record
PAH	polycyclic aromatic hydrocarbon
PBDEs	polybrominated diphenyl ethers
PCB	polychlorinated biphenyl
ppm	parts per million
RM	river mile
RME	reasonable maximum exposure
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ	2,3,7,8-TCDD toxic equivalent
UCL	upper confidence limit on the mean
W	west
WDOE	Washington Department of Ecology

1.0 SUMMARY OF BASELINE HUMAN HEALTH RISK ASSESSMENT

The overall objective of the baseline human health risk assessment ([BHHRA], Kennedy/Jenks 2011) was to evaluate whether exposure to contaminants in sediment, surface water, groundwater seeps, or biota may result in unacceptable risks to human health. The BHHRA was conducted in accordance with technical guidance and other requirements set forth by the United States Environmental Protection Agency (EPA) and the Oregon Department of Environmental Quality (DEQ). The focus area of the BHHRA was the approximate 10-mile portion of Portland Harbor from river mile (RM) 1.9 to RM 11.8, which is referred to as the Study Area. The results of the BHHRA will be used in developing remedial action objectives and assist in risk management decisions to be made by EPA for the Portland Harbor Superfund Site. The results of the BHHRA are also used in developing risk management recommendations for the site, as discussed in the main text of this document.

This attachment provides a summary of the risks for each of the media evaluated for potential risks in the BHHRA (fish tissue, shellfish tissue, in-water sediment, beach sediment, surface water, and groundwater seeps), similar to information presented in Section 7 of the BHHRA. The summary discusses the risks for the exposure scenarios evaluated in the BHHRA, identifies the contaminants potentially posing unacceptable risks for those scenarios, and briefly presents the significant uncertainties associated with those scenarios resulting in cancer risks greater than 1×10^{-6} or hazard indices (HI) greater than 1. Figures 1 and 2 show the ranges of cumulative cancer risks and HIs, respectively, for each receptor evaluated in the BHHRA exposure scenarios. A summary of the major uncertainties in the BHHRA is presented in Table 1. These uncertainties should be considered in the Feasibility Study (FS) in evaluating remedies that would be protective of human health.

1.1 FISH CONSUMPTION

Fish consumption risks for adult and child non-tribal consumers were evaluated in the BHHRA based on three different ingestion rates each. Fish consumption risks were evaluated for both single species- and multi-species diets (including common carp, black crappie, brown bullhead, and smallmouth bass), based on consumption of either whole body or fillet with skin tissue. It was assumed that all fish consumed were resident fish caught within the Study Area or within a single exposure area for spatial scales smaller than the Study Area.

Consumption of individual species by the non-tribal fisher resulted in cumulative cancer risks ranging from 3×10^{-6} to 7×10^{-2} for the scenarios including adult fisher, child fisher, combined adult and child fisher, or breastfeeding infant of an adult fisher consuming fish. For all species and consumers, PCBs are the primary risk contributor. The maximum endpoint-specific HI for both adult and child fish consumption scenarios was for the immunological endpoint, primarily due to consumption of polychlorinated biphenyls (PCBs) in tissue. The highest HI for the immunological endpoint occurs from child consumption of whole body common carp tissue from RM 4 to RM 8. The cumulative HIs range from 0.5 to 5,000 for the child and adult non-tribal fish consumers. The highest HI was 60,000 for the breastfeeding infant of a non-tribal fish consumer. Risks from fish consumption by non-tribal fishers are primarily from exposure to PCBs in fish tissue.

Fish consumption risks were also evaluated for adult and child tribal fishers in the BHHRA based on the 95th percentile ingestion rate from the Columbia River Inter-Tribal Fish Commission (CRITFC) Consumption Study (1994). The tribal fish consumption risks assumed a multi-species diet consisting of resident fish species (common carp, black crappie, brown bullhead, and smallmouth bass) as well as sturgeon, lamprey, and salmon. Risks from the tribal fish diet were based on consumption of either whole body or fillet with skin tissue. It was assumed that all fish consumed were caught within the Study Area. Consumption of fish by the tribal fisher resulted in cumulative cancer risks ranging from 2×10^{-3} to 2×10^{-2} for the tribal adult fisher and from 4×10^{-4} to 3×10^{-3} for the tribal child consumer. The maximum endpoint-specific HIs for both the tribal adult and tribal child fishers were for the immunological endpoint, primarily due to consumption of PCBs in fish tissue. The range of cumulative HIs for fish consumption was from 50 to 400 for the tribal adult and from 100 to 800 for the tribal child.

1.1.1 Contaminants Posing Potentially Unacceptable Risks

Twenty six contaminants resulted in a cancer risk greater than 1×10^{-6} or hazard quotient greater than 1 for at least one of the fish consumption scenarios evaluated in the BHHRA. The contaminants identified as posing potentially unacceptable risks were: PCBs, dioxins/furans, six metals (antimony, arsenic, lead, mercury, selenium, and zinc), bis 2-ethylhexyl phthalate (BEHP), polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene, seven pesticides (aldrin, dieldrin, heptachlor epoxide, total chlordane, total dichlorodiphenyldichloroethane [DDD], total dichlorodiphenyldichloroethylene [DDE], total dichlorodiphenyltrichloroethane [DDT]), and polybrominated diphenyl ethers (PBDEs). Of these, PCBs resulted in the highest cancer risks and hazard quotients.

1.1.2 Key Uncertainties

There were multiple uncertainties associated with the fish consumption scenarios of which the following were of primary significance: a) uncertainty in the cancer slope factor for PCBs and other chemical cancer slope factors and reference doses; b) consumption rates and patterns determined with lack of site-specific fish consumption information; c) the small fishing area assumed for exclusive collection of fish consumed during the course of multiple years (child fisher) or a lifetime (adult fisher); and d) concentrations of PCBs and other chemicals in tissue which includes tissue type and fish species consumed, cooking and preparation methods, and contributions from background.

Each of the assumptions regarding fish ingestion rates, tissue type, fish species consumed, and the use of cooking and preparation methods used in the BHHRA resulted in an upper-bound estimate of the value for that variable, typically representing the 90th to 99th percentile for exposure. When combined, these assumptions result in risk estimates that are considered to be at the upper-end of the reasonable maximum exposure (RME) range (i.e., 90th to 99.9th percentile).

1.2 SHELLFISH CONSUMPTION

Shellfish consumption risks were evaluated in the BHHRA for non-tribal adult fishers based on two different ingestion rates: 3.3 grams per day (g/day) and 18 g/day. Shellfish consumption risks were evaluated separately for both freshwater bivalves (i.e. clams) and crayfish, based on whole body tissue without the shell. As with fish consumption, it was assumed that all shellfish consumed were caught within the Study Area or at a single location for exposure areas smaller than the Study Area. In addition, clam consumption risks were evaluated separately for depurated and undepurated tissue. Consumption of shellfish by the adult fisher resulted in cumulative cancer risks ranging from 9×10^{-7} to 7×10^{-4}. The cumulative HIs range from 0.06 to 40 for shellfish consumption. The highest HI was 800 for the breastfeeding infant of a shellfish consumer. The maximum endpoint-specific HI for the shellfish consumption scenarios was for the immunological endpoint, due primarily to consumption of PCBs in shellfish tissue.

1.2.1 Contaminants Posing Potentially Unacceptable Risks

Seventeen contaminants were identified as potentially posing unacceptable risks for shellfish consumption, based on exceedances of the cumulative cancer risk of 1×10^{-6} or hazard quotient greater than 1 for at least one of the shellfish consumption scenarios evaluated in the BHHRA. The contaminants potentially posing unacceptable risks for at least one of the crayfish consumption scenarios were: PCBs, dioxins/furans, arsenic, PAHs, pentachlorophenol, and total DDE. The contaminants potentially posing unacceptable risks for at least one of the clam consumption scenarios were: PCBs, dioxins/furans, arsenic, PAHs, and five pesticides (aldrin, dieldrin, total DDD, total DDE, and total DDT). Of these, PCBs resulted in the highest cancer risks and hazard quotients.

1.2.2 Key Uncertainties

In addition to the uncertainty of whether shellfish consumption actually occurs on an ongoing basis, there were other uncertainties associated with the shellfish consumption scenarios of which the following were of primary significance: spatial scale of exposure point concentrations (EPCs), shellfish consumption rates, shellfish species consumed, exposure duration, use of undepurated tissue in risk estimates, cooking and preparation methods, and contributions from background.

Significant uncertainties associated with the shellfish consumption scenario result in conservative estimates of risk for this exposure route.

1.3 DIRECT EXPOSURE TO IN-WATER SEDIMENT

Risks from direct exposure to in-water sediment were evaluated in the BHHRA for six different adult receptors: in-water workers conducting over-water activities, tribal fishers, low- and high-frequency fishers, commercial divers in wet suits, commercial divers in dry suits, and breastfeeding infants of these adult receptors. The diver in a dry suit was evaluated for a RME scenario only. Risks were assessed on a Study Area wide basis, and on a half-river mile basis per side of river. Risks from in-water sediment exposure were also calculated for three river segments outside of the Study Area, however, Study Area-wide risks were calculated only for samples within the Study Area. In-water sediment within the navigation channel was not included in the risk evaluation.

Direct contact with in-water sediment resulted in cumulative cancer risks ranging from 5 x 10^{-9} to 3 x 10^{-4} across all scenarios. The only HI that was greater than 1 was for the tribal fisher and high frequency fisher RME scenarios, and their breastfeeding infants, due to dioxin/furans, which occurred at the ½-mile exposure area at RM 7 west (W). The highest cumulative cancer risks and HIs from direct contact with in-water sediment were for the tribal fisher scenario.

1.3.1 Contaminants Posing Potentially Unacceptable Risks

Four contaminants resulted in a cancer risk greater than 1 x 10^{-6} or hazard quotient greater than 1 for at least one of the in-water sediment scenarios: PCBs, dioxins/furans, arsenic, and PAHs. PAHs and dioxins/furans were identified as contaminants posing potentially unacceptable risks for all of the in-water sediment scenarios. Arsenic was identified as a contaminant potentially posing unacceptable risks for tribal fisher and high frequency fisher scenarios only, and PCBs were identified as a contaminant potentially posing unacceptable risks only for the tribal fisher scenario. Cancer risks associated with arsenic may be due in part to naturally occurring background sediment concentrations. Cumulative cancer risks above 1 x 10^{-6} for PCBs are associated with only three ½-mile river segments, and for dioxins/furans are associated with only two ½-mile river segments. Cumulative cancer risks above 1 x 10^{-6} for PAHs are associated with 22 ½-mile river segments.

1.3.2 Key Uncertainties

There were multiple uncertainties associated with the direct exposure to in-water sediment scenarios of which the following were of primary significance: degree of sediment contact that occurs during fishing scenarios, spatial scale of in-water sediment EPCs, exposure parameters, bioavailability of contaminants in sediment, contributions from background, and the inclusion of a wet suit diver scenario. The uncertainties associated with exposure parameters and contributions from background were not quantified in the BHHRA.

1.4 DIRECT EXPOSURE TO BEACH SEDIMENT

Risks from direct exposure to beach sediment were evaluated in the BHHRA for seven receptors: dockside workers, transients, adult and child recreation beach users, tribal fishers, low- and high-frequency fishers, and breastfeeding infants of these receptors. Risks were evaluated per beach, based on known and potential uses of each beach area.

Direct contact with beach sediment resulted in cumulative cancer risks ranging from 8 x 10^{-9} to 9 x 10^{-5}. The highest cumulative cancer risks at industrial use beaches were for the dockside worker scenario, and the highest cumulative cancer risks at residential use beaches were for the tribal fisher scenario.

The only central tendency (CT) scenarios for exposure to beach sediment resulting in risks above 1 x 10^{-6} were the dockside worker (6 x 10^{-6}) and tribal fisher and child recreational beach user scenarios (2 x 10^{-6}). The cumulative cancer risks for all of the CT scenarios were below 1 x 10^{-4}. The RME scenarios for exposure to beach sediment resulting in cumulative cancer risks above 1 x 10^{-6} include: dockside worker, adult and child recreational beach user, tribal fisher and fisher. The maximum cancer risk from RME scenarios was 9 x 10^{-5} for the dockside worker exposure to beach sediment. None of the RME scenarios for exposure to beach sediment resulted in risks greater than 1 x 10^{-4}. None of the scenarios resulted in HIs exceeding 1. Risks above 1 x 10^{-6} resulting from exposures to beach sediment are due primarily to arsenic, which is likely present at naturally occurring background concentrations, and benzo(a)pyrene.

1.4.1 Contaminants Posing Potentially Unacceptable Risks

Two chemicals resulted in a cancer risk greater than 1 x 10^{-6} or hazard quotient greater than 1 for at least one of the scenarios evaluated for direct contact with beach sediment in the BHHRA: arsenic and PAHs.

1.4.2 Key Uncertainties

There were multiple uncertainties associated with the direct exposure to beach sediment scenarios of which the following were of primary significance: spatial scale of beach sediment EPCs, exposure parameters, bioavailability of contaminants in sediment, the compositing methods for beach sediment sampling, and contributions from naturally occurring arsenic in soil (background). The uncertainties associated with exposure parameters and contributions from background were not quantified in the BHHRA.

Uncertainties associated with sample compositing could bias risk results high or low; uncertainties associated with background concentrations of arsenic in beach sediment are likely to provide a conservative estimate of risk for direct exposure to beach sediment.

1.5 DIRECT EXPOSURE TO SURFACE WATER

Potential risks from direct exposure to surface water through ingestion and dermal absorption were evaluated in the BHHRA for transients, recreational beach users, and divers. In addition, potential risks were estimated for a hypothetical future use of surface water as a domestic water source. Both integrated and non-integrated water column surface water samples were collected within the Study Area and were used in estimating the surface water EPCs. The specific surface water samples used to estimate EPCs for each receptor were dependent upon the exposures of that receptor to surface water within the Study Area.

Direct contact with surface water resulted in cumulative cancer risks ranging from 8×10^{-10} to 9×10^{-4} across all scenarios, including hypothetical future use as a domestic water source. The maximum cumulative cancer risk was for hypothetical exposure to untreated surface water and was 9×10^{-4}, due primarily to carcinogenic PAHs, and benzo(a)pyrene specifically. Other scenarios resulting in cumulative cancer risks greater than 1×10^{-6} were the diver in wet suit (1×10^{-5}) and the diver in dry suit (2×10^{-6}) at RM 6W due primarily to carcinogenic PAHs. The only HIs that were greater than 1 were for hypothetical future use as a domestic water source by a child resident under the RME scenario.

1.5.1 Contaminants Posing Potentially Unacceptable Risks

Four contaminants resulted in a cancer risk greater than 1×10^{-6} or hazard quotient greater than 1 for at least one of the surface water scenarios evaluated in the BHHRA: 2-(2-Methyl-4-chlorophenoxy)propionic acid (MCPP), arsenic, hexavalent chromium, and PAHs.

1.5.2 Key Uncertainties

One of the designated beneficial uses of the Willamette River is domestic water supply with adequate pretreatment. EPA required that potential risks be estimated for a hypothetical future use of surface water as a domestic water source assuming no pretreatment. However, there is no known current or anticipated future use of the Willamette River within the Study Area as a domestic water source. Furthermore, if such use were to occur in the future, adequate pretreatment to meet Safe Drinking Water Act standards and Oregon rules would be required. Therefore, there is significant uncertainty in the evaluation of untreated surface water as a domestic water source.

The most significant uncertainty associated with the risk assessment of direct exposure to surface water is the spatial scale of exposure areas, specifically for the diver scenarios. There is also some uncertainty in the representativeness of this dataset for surface water conditions for recreational users.

Uncertainties associated with exposure parameter values and spatial scale of exposure area resulted in conservative estimates of risk from direct contact with surface water.

Uncertainties associated with the representativeness of the data set could over or under estimate risk.

1.6 DIRECT EXPOSURE TO GROUNDWATER SEEPS

Risks from direct exposure to groundwater seeps were evaluated for a transient. The only groundwater seep where direct contact could occur within the Study Area is within the potential transient use area located on the west side of the river at RM 7. Outfall 22B, which is a potential conduit of groundwater discharge in the seep water present on that beach, was sampled twice between 2002 and 2007 at times that did not involve stormwater influence. Analytical results from these two sampling events were used to evaluate risks for this scenario.

Risks from exposures to groundwater seeps were evaluated for exposure by a transient for only one exposure point. The transient exposure scenario did not result in cumulative cancer risks greater than 1 x 10^{-6} or HIs greater than 1.

1.6.1 Contaminants Posing Potentially Unacceptable Risks

There are no chemicals posing potentially unacceptable risks for direct exposure to groundwater seeps.

1.6.2 Key Uncertainties

This document focuses on uncertainties associated with cancer risks greater than 1 x 10^{-6} or hazard indices greater than 1 in order to inform EPA's risk management decisions. Since this scenario did not result in unacceptable risks, the reader is referred to the BHHRA for a discussion of uncertainties related to this scenario.

2.0 EVALUATION OF PATHWAYS AND CONTAMINANTS POSING POTENTIALLY UNACCEPTABLE RISKS

This section provides a detailed evaluation of each contaminant identified as posing potentially unacceptable risks by exposure pathway, focusing on the magnitude of risk, the scale of risk, the frequency of detection, and uncertainties associated with the risk. Each detailed evaluation provides a recommendation as to whether the contaminant should be considered a contaminant of concern (COC) in the FS. The contaminants identified in the BHHRA as potentially resulting in cancer risks greater than 1×10^{-6} or a HQ greater than 1 are presented in Table 3 for each of the exposure pathways.

Only those exposure pathways and contaminants that resulted in a cancer risk greater than 1×10^{-6} or an HQ greater than 1 were considered in the recommendations of COCs. Additional considerations in the recommendation of COCs included:

- The relative percentage of each contaminant's contribution to the total human health risk consistent with assumptions on exposure areas.
- Frequency of cancer risks greater than 1×10^{-6} or hazard quotients greater than 1, both on a localized basis and Study Area-wide.
- Potential contributions from background concentrations to the cancer risks and noncancer hazards.
- Magnitude of risk exceedance above EPA's target range for managing cancer risk of 1×10^{-4} to 1×10^{-6} and noncancer hazard of one.

The contaminants potentially posing unacceptable risks and the recommended COCs based on the above criteria for the exposure pathways evaluated in the BHHRA are discussed below. In addition, an explanation is given for contaminants potentially posing unacceptable risks that are not recommended as COCs.

2.1 FISH CONSUMPTION

Twenty six chemicals (PCBs, dioxins/furans, six metals, BEHP, PAHs, hexachlorobenzene, seven pesticides, and PBDEs) resulted in exceedances of a cancer risk of 1×10^{-6} or HQ of 1 for the fish consumption scenarios (i.e., both fisher and tribal fisher) evaluated in the BHHRA. These chemicals and the respective risk management considerations used in recommending the COCs for fish consumption are summarized in Table 4.

The range of ingestion rates used in the BHHRA results in cancer risks and noncancer hazards that span an order of magnitude. For chemicals where the ranges of cancer risks and noncancer hazards are greater than an order of magnitude, differences in species, tissue types, and exposure areas contribute to the range of cancer risks and hazard quotients (HQs).

For purposes of comparing cancer risks from individual chemicals across different species, the risk estimates for the non-tribal adult fish consumption scenario were used because the non-tribal adult fish consumption resulted in the highest cancer risks of the scenarios evaluated in the BHHRA. For purposes of comparing noncancer hazards, the risk estimates for the non-tribal child fish consumption scenario were used because the non-tribal child fish consumption resulted in the highest noncancer hazards of the scenarios evaluated for all chemicals in the BHHRA. The breastfeeding infant of a non-tribal adult fish consumer resulted in the highest noncancer hazards but was only evaluated for the bioaccumulative chemicals for which infant risk adjustment factors have been developed in DEQ guidance. Thes e are: PCBs, dioxins/furans, total DDx. In addition, infant risk from exposure to PBDEs in breastmilk was evaluated. While the magnitude of risk would change for scenarios other than those used in the figures presented in this report, the relative risks from the different species and ingestion rates would be the same.

2.1.1 PCBs

PCBs are a primary contributor to cumulative cancer risk and result in the highest HQs for fish consumption. Collectively, total PCBs and PCB TEQ contribute approximately 74 and 71 percent of the cumulative cancer risk for the smallmouth bass single species diet for whole body and fillet, respectively, on a Study Area-wide basis. For the multi-species diet, total PCBs and PCB TEQ contribute to approximately 93 and 97 percent of the Study Area-wide cumulative cancer risk, for whole body and fillet, respectively.

Figures 3 and 4 display the ranges of total PCB and PCB TEQ cancer risk estimates, respectively, for all four resident fish species, all three ingestion rates, and both the 95% upper confidence limit on the mean (UCL) /maximum detected concentration EPCs and mean EPCs for the non-tribal adult fisher scenario. Figures 5 and 6 show the ranges of total PCB and PCB TEQ hazard quotients, respectively, for the non-tribal child consumer. Total PCBs resulted in cancer risk estimates exceeding 1×10^{-4} and/or HQs exceeding 1 for the majority of the fish consumption scenarios evaluated in the BHHRA. Total PCB TEQ also resulted in cancer risk estimates exceeding 1×10^{-4} and/or HQs exceeding 1 for the majority of the fish consumption scenarios evaluated in the BHHRA. PCBs resulted in risk estimates that exceeded a cancer risk of 1×10^{-4} and/or HQ of 1 for both localized and Study Area-wide exposures evaluated in the BHHRA.

The ranges in cancer risks and HQs for PCBs in fish tissue spanned orders of magnitude depending on the exposure assumptions that were used in the BHHRA. The maximum risks for PCBs are for fish consumption scenarios based on consumption of whole body tissue only at an ingestion rate of 142 g/day of smallmouth bass or carp from a single exposure area. For example, the maximum cancer risk for total PCBs in smallmouth bass tissue was 1×10^{-2}, and the maximum HQ was 700, associated with consumption of whole body tissue from a single river mile and an ingestion rate of 142 g/day for a period of 30 years. Total PCBs in smallmouth bass fillet tissue (with skin on) resulted in a cancer risk of 1×10^{-4} and a HQ of 6 based on the ingestion rate of 17.5 g/day and on a

Study Area-wide basis. The BHHRA did not account for changes in tissue concentrations due to preparation and cooking methods, which would likely result in lower risks for PCBs. The EPA (1997) states that "cleaning and cooking techniques may reduce the levels of some chemical pollutants in the fish."

PCBs are commonly detected in fish tissue collected in the Willamette and Columbia Rivers, outside of the Study Area. Such con centrations reflect sources of PCBs that are not related to those associated with the Study Area. The likely sources include contribution from other point sources, but also reflect general anthropogenic sources of PCBs that are not reducible based on point remediation of sites related to the Comprehensive Environmental Recovery, Compensation and Liability Act (CERCLA).

The average concentrations of PCBs from the mid-Willamette River, Columbia River Basin, upstream of Portland Harbor, and the Study Area are presented in Table 5. In the Columbia River Basin Fish Contaminant Survey, the basin-wide average concentrations of total PCBs in resident fish ranged from 32 to 173 micrograms per kilogram (μg/kg) for whole body samples and from 30 to 190 μg/kg for fillet with skin samples (EPA 2002). In the Middle Willamette River (RM 26.5 to RM 72), the average concentrations of total PCBs in resident fish ranged from 86 to 146 μg/kg for whole body samples and from 26 to 71 μg/kg for fillet with skin samples (EVS 2000). The average concentrations of total PCBs in whole body fish tissue samples collected upstream of the Study Area (RM 20 to RM 28) were 33 μg/kg and 169 μg/kg in brown bullhead and smallmouth bass, respectively. The average concentrations for total PCBs in fish tissue collected within the Study Area ranged from 24 μg/kg in black crappie to 2,521 μg/kg in carp for fillet with skin tissue and from 164 μg/kg in black crappie to 2,757 μg/kg in carp for whole body tissue. While the highest average concentrations of total PCBs associated with the Study Area are higher than total PCB concentrations in fish tissue collected outside of the area (EPA 2002, EVS 2000), the regional fish tissue concentrations are indicative of regional cancer risk levels exceeding 1×10^{-6} for the ingestion rates evaluated in the BHHRA (17.5 g/day, 73 g/day, and 142 g/day).

PCBs are recommended as a COC for the fish consumption pathway because of the relative contribution to cumulative risk, spatial scale of the risk exceedances, and magnitude of the risk exceedances above the EPA target range for managing risk for the majority of the fish consumption scenarios evaluated in the BHHRA. The uncertainties associated with the risks from PCBs also need to be considered in the development and evaluation of remedies in the FS. Given the regional fish tissue concentrations, it likely is not achievable for the site to attain cancer risk levels below 1×10^{-6} or HQ of 1 considering the exposure assumptions of the BHHRA. However, risk reduction may be an achievable risk management goal for the site.

2.1.2 Dioxin/Furans

Dioxins/furans are a secondary contributor to the cumulative cancer risk and also result in HQs greater than 1. Collectively, dioxins/furans contribute approximately 21 percent of the cumulative cancer risk for the smallmouth bass single species diet, and approximately 5 percent of the cumulative cancer risk in the multi-species diet on a Study Area-wide basis (whole body tissue). Total dioxin TEQ resulted in risk estimates that exceeded a cancer risk of 1 x 10^{-4} and/or HQ of 1 for both localized and Study Area-wide exposures. Figure 7 displays the ranges of total dioxin TEQ cancer risk estimates for 95% UCL and mean EPCs for the non-tribal adult fisher, and Figure 8 shows the ranges of total dioxin TEQ noncancer hazard estimates for the non-tribal child.

The ranges in cancer risks and HQs for total dioxin TEQ spanned orders of magnitude depending on the exposure assumptions that were used in the BHHRA. The range of cancer risk estimates for total dioxin TEQ spanned three orders of magnitude and exceeded the 1 x 10^{-6} point of departure cancer risk level for all resident fish species, all three ingestion rates, and for both 95% UCL and mean EPCs. The maximum cancer risk estimate (6 x 10^{-3}) and HQ (100) for total dioxin TEQ were based on the ingestion rate of 142 g/day and consumption of whole body tissue for smallmouth bass caught within a single river mile. For smallmouth bass fillet tissue (with skin), total dioxin TEQ, based on the ingestion rate of 17.5 g/day and on a Study Area-wide basis, resulted in a cancer risk of 4 x 10^{-5} and a HQ less than 1. The BHHRA did not account for changes in tissue concentrations due to preparation and cooking methods, which would likely result in lower risks for dioxin/furans. EPA guidance (1997) states that "cleaning and cooking techniques may reduce the levels of some chemical pollutants in the fish."

Dioxin/furans are recommended as a COC for the fish consumption pathway because of the magnitude of the risk exceedances, spatial scale of the risk exceedances, and relative contribution to cumulative risk. The uncertainties in the risk estimates should be considered further in the FS.

2.1.3 Metals

Several metals were associated with one or more fish consumption exposure scenarios that resulted in a risk estimate that exceeded a cancer risk of 1 x 10^{-6} or HQ of 1. Arsenic was associated with cancer risk estimates exceeding the point of departure level of 1 x 10^{-6}. Antimony, mercury, selenium, and zinc were associated with exceedances of a HQ of 1.

2.1.3.1 Arsenic

Arsenic resulted in cancer risk estimates that exceeded a cancer risk of 1 x 10^{-6} for both localized and Study Area-wide exposures, for all resident fish species scenarios, and at all ingestion rates for both adult and child non-tribal fish consumers. Arsenic contributes less than 1% of the cancer risk for the multi-species diet. Figure 9 displays the ranges of cancer risk estimates associated with consumption of arsenic in resident fish tissue by a non-tribal adult fisher.

Arsenic resulted in cancer risk estimates for the adult non-tribal fish consumer scenario that ranged from 3 x 10^{-7} (brown bullhead fillet tissue at 17.5 g/day ingestion rate) to 5 x

10^{-5} (black crappie whole body tissue at 142 g/day ingestion rate). As shown in Figure 9, the ranges of risks for a given species and tissue type are generally about an order of magnitude, indicating that the exposure point concentrations do not vary significantly throughout the Study Area for a given species and tissue type. Resident fish tissue arsenic EPCs, calculated as inorganic arsenic, ranged from 0.002 milligrams per kilogram (mg/kg) (brown bullhead fillet tissue) to 0.042 mg/kg (black crappie whole body tissue). Arsenic concentrations in fish tissue are due (in part) to naturally occurring concentrations in sediment and surface water; however, the magnitude of contribution from background concentrations of arsenic is not known.

Arsenic is not recommended as a COC in the FS because of the likely contribution of background to the risks. The ranges of risks indicate that exposure point concentrations are similar throughout the Study Area for a given species and tissue type. Given that arsenic concentrations in fish tissue are due (in part) to naturally occurring sediment and surface water concentrations, it may not be achievable to reduce cancer risk levels associated with arsenic in fish tissue to below the point of departure risk level of 1×10^{-6}. Furthermore, arsenic has a low relative magnitude of cancer risk estimates.

2.1.3.2 Antimony

Antimony (a non-carcinogen) resulted in only one exceedance of a HQ of 1, which was associated with consumption of whole body smallmouth bass tissue and only due to a single smallmouth bass sample (RM 10) with an anomalously high result. Figure 10 presents the ranges of HQ estimates for antimony in resident fish for the non-tribal child scenario. The smallmouth bass sample collected during the Round 3 sampling effort at RM 10 east (E) (LW3-SB010E-C00B) resulted in anomalously high detected concentrations of lead and antimony in the tissue analyzed as whole body without fillet. The tissue sample was reanalyzed and due to the consistently high detection of these compounds in this sample, the results of the lead and antimony analyses for this sample were averaged for use in the BHHRA. As discussed in the Round 3B Fish and Invertebrate Tissue and Collocated Sediment Data Report, Addendum 1 (Integral 2008), the elevated concentrations of lead and antimony are consistent with what would be expected from fish that swallowed fishing gear (e.g. a sinker) containing lead and antimony or other similar metal objects. These concentrations may not have been representative of tissue concentrations resulting from exposure to CERCLA-related contamination within the Study Area. The antimony concentration in body without fillet tissue for this sample was 8.41 mg/kg, which was approximately 160 times higher than the next highest antimony concentration in smallmouth bass tissue collected within the Study Area.

The concentration of antimony for the sample (LW3-SB010E-C00WB) was the maximum concentration for the RM 10 smallmouth bass exposure area, and due to the low number of smallmouth bass samples within the exposure area, it was used as the EPC. The maximum concentration of this sample is an extremely conservative estimate of exposure from this river mile stretch, and does not represent average exposure from consuming smallmouth bass tissue collected at this exposure area. The antimony concentration from this sample was also used in the calculation of Study Area-wide EPCs for smallmouth bass, creating a high bias in the dataset. Antimony would not be associated with an exceedance of a HQ of 1 if the smallmouth bass sample collected RM 10 E (LW3-SB010E-C00B) was removed from the BHHRA data set.

Antimony is not recommended as a COC in the FS because of the low frequency of an exceedance of a HQ of 1 and the uncertainty in the smallmouth bass tissue data associated with the HQ exceedance.

2.1.3.3 Lead

Human health risks from consumption of lead in fish tissue were assessed by comparing fish tissue EPCs to modeled protective fish tissue concentrations. The protective fish tissue concentrations were determined using blood lead level models (See Section 5.2.8.2 of the BHHRA). The maximum EPC for lead was greater than the protective tissue concentrations associated with an acceptable probability of exceeding protective blood lead levels in the fetus of a pregnant woman ingesting tissue from the Study Area. However, this maximum EPC is orders of magnitude greater than all other fish tissue EPCs for lead and may be attributable to lead in the gut of the fish. Lead concentrations in fish tissue exceeded the respective protective fish tissue concentrations due to the influence of only one sample that created bias in the smallmouth bass and multispecies data sets.

As described for antimony, an elevated concentration of lead was detected in the smallmouth bass sample collected at RM 10E (LW3-SB010E-C00WB) that was considered an anomalously high result relative to other detected lead concentrations in fish tissue. The lead concentration in body without fillet tissue for this sample was 1,640 mg/kg, which was over 600 times higher than the next highest lead concentration for smallmouth bass collected within the Study Area. The concentration of lead for this sample (LW3-SB010E-C00WB) was the maximum concentration for the RM 10 smallmouth bass exposure area, and due to the low number of smallmouth bass samples within the exposure area, it was used as the EPC. The lead concentration from this sample was also used in the calculation of Study Area-wide EPCs for smallmouth bass, creating a high bias in the dataset. As shown in Table 6, the sediment concentrations of lead in RM 10 are actually similar to or lower than concentrations throughout the Study Area.

In addition to the uncertainty associated with the use of the maximum detected concentration as the EPC, there is uncertainty in the risk assessment methodology used to evaluate lead in fish tissue. Target tissue concentrations were estimated using the EPA Adult Lead Methodology (ALM) (EPA 2003), based on agreements with the EPA to follow the same methodology used in the CRITFC study (1994) to assess tissue exposures from lead. The ALM focuses on potential impacts to the fetus of a pregnant worker, and therefore, is only appropriate when considering fish consumption by pregnant women. The ALM was developed based on exposure to lead in soil and may not be appropriate to use for fish consumption. Furthermore, the ALM is highly sensitive to the bioavailability of ingested lead. For purposes of developing the target tissue concentrations, the default bioavailability of lead in soil was used. It is not known whether this is an appropriate assumption for lead in tissue.

The identification of lead as a chemical potentially posing unacceptable risk was based on the maximum detected concentration, which may not be due to CERCLA activities, and is not representative of Study Area-wide lead concentrations. If the smallmouth bass sample LW3-SB010E-C00WB was removed from the BHHRA dataset, then lead would not exceed the target tissue concentrations. Furthermore, the identification of lead as a chemical potentially posing unacceptable risk was based on the ALM, which was not developed for fish consumption. As a result, lead is not recommended as a COC in the FS given the uncertainties associated with the EPCs and risk assessment methodology.

2.1.3.4 Mercury

Mercury was associated with exceedances of a HQ of 1 for consumption of all four of the resident fish species and for both localized and Study Area-wide exposure areas. Figure 11 presents the ranges of HQ estimates for mercury in resident fish for the child non-tribal consumer scenario. The maximum HQ for mercury (10) was based on consumption of smallmouth bass fillet tissue at the consumption rate of 60 g/day for the child non-tribal consumer. Based on an ingestion rate of 60 g/day, the range of HQs for all of the four resident fish species spanned only one order of magnitude (HQs of 1 to 10). This narrow range of HQ estimates indicates that there is little variability in mercury fish tissue concentrations for resident species collected within the Study Area.

Mercury concentrations in fish tissue caught within the Study Area are due (in part) to naturally occurring concentrations of mercury in sediment and surface water. The Oregon Department of Health Services (DHS) established a fish advisory for mercury in resident fish species for the entire main stem of the Willamette River, which includes main stem reaches upstream of Portland Harbor (DHS 2007). The DHS (2007) states that mercury in fish, "…. is believed to come from natural volcanic and mineral sources in the headwaters of the river and possibly from a number of man-made sources along the river."

The DHS developed Oregon fish advisories for mercury based on a fish tissue concentration of 0.35 mg/kg (parts per million [ppm]). The DHS (1999) states that an overall average mercury level of 0.35 ppm is the "screen value," which serves as a "red flag that fish from that water body may pose hazards to consumers." The DHS (1999) also states that "in cases in which the average mercury level is less than the screen value, but it is known that there is a population of consumers that eat abnormally large amounts of the fish; or if there is a population of consumers that has abnormal susceptibility to fish mercury, the Health Division may issue advisories for those unique conditions." The EPCs of mercury in resident fish tissue collected within the Study Area ranged from 0.037 ppm (back crappie) to 0.35 ppm (smallmouth bass). The majority of mercury concentrations detected in resident fish tissue collected within the Study Area are below the screening value that DHS has established for evaluating the need for fish advisories.

Mercury is not recommended as a COC in the FS because naturally occurring sources of mercury contribute (in part) to the fish tissue concentrations. It may not be possible to achieve a HQ of 1 for resident fish species collected within the Study Area given that there is a fish advisory for resident fish species for the entire main stem of the Willamette River that is based on average tissue concentrations exceeding 0.35 ppm, which would result in HQs greater than 1 for the assumptions used in the BHHRA.

2.1.3.5 Selenium

Selenium was associated with an exceedance of the HQ of 1 for fish consumption based on a single sample of fillet smallmouth bass tissue collected at RM 11. Figure 12 presents the ranges of HQ estimates for selenium in resident fish for the child non-tribal consumer scenario. For the highest ingestion rates, the selenium detection in the smallmouth bass tissue sample collected at RM 11 was associated with HQs of 4 and 2 for the non-tribal child fish consumer and the non-tribal adult fish consumer, respectively. Selenium was not detected in the majority of the smallmouth bass tissue samples; selenium was reported as non-detect for seventeen of the 21 whole body and fillet smallmouth bass samples. As shown in Table 7, the detection limits for selenium were less than the target tissue levels associated with an HQ of 1, indicating that selenium would not result in potentially unacceptable risks in the samples where it was not detected.

Selenium is not recommended as a COC in the FS because of the low frequency exceedance of a HQ of 1, the low magnitude of the exceedance, and because the majority of resident fish tissue samples did not contain detected concentrations of selenium.

2.1.3.6 Zinc

Zinc was associated with only one exceedance of a HQ of 1 for fish consumption, for which the HQ estimate was 2. Figure 13 presents the ranges of HQ estimates for zinc in resident fish for the child non-tribal consumer scenario. The HQ estimate of 2 was associated with the child non-tribal fisher consuming only whole body common carp tissue at the highest ingestion rate of 60 g/day, and for only the fishing zone from RM 4 to RM 8.

Zinc is not recommended as a COC in the FS because of the low frequency of the HQ exceedance (only one EPC and for only the highest ingestion rate), and the low magnitude of the exceedance (HQ of 2 only slightly exceeds a HQ of 1).

2.1.4 BEHP

BEHP resulted in cancer risks estimates greater than 1×10^{-6} for consumption of whole body smallmouth bass and brown bullhead tissue, based on both a localized and Study Area-wide basis, for all ingestion rates. Figure 14 displays the cancer risk estimates for consumption of BEHP in fish by an adult non-tribal fisher. BEHP resulted in cancer risk estimates greater than 1×10^{-4} and HQs greater than 1 for consumption of whole body smallmouth bass (RM 4) at the ingestion rates of 142 g/day and 73 g/day.

BEHP was reported as non-detected in the majority of smallmouth bass tissue analyzed; BEHP was not detected in 14 samples of the 21 whole body and fillet smallmouth bass composite samples. BEHP was not detected in two of the four composite brown bullhead samples, and was not detected in any of the common carp or black crappie whole body or fillet tissue composite samples.

The chemical BEHP, also known as di(2-ethylhexyl) phthalate (DEHP), is a plasticizer that is found in many industrial and consumer products. The Agency for Toxic Substance and Disease Registry (ATSDR) (2002) notes that "….DEHP is widespread in the environment." Furthermore, phthalates are used in many plastic fishing lures (ScienceDaily 2008). The Round 3 fish tissue data allow for a comparison between fillet and whole body concentrations in the same fish. In the Round 3 smallmouth bass, the highest detected concentrations of BEHP (2800 μg/kg) were in whole body samples collected from RM 10E and RM 11W. BEHP was not detected in the fillet samples of those fish. There were fish where BEHP was detected in both the whole body and fillet samples; however, the detected concentrations in those fish (44 – 100 μg/kg) were much lower and did not result in cancer risks greater than 1 x 10^{-6} or HQs greater than 1.

Concentrations of BEHP in smallmouth bass whole body and fillet samples are shown in Table 8. Given that the highest concentrations of BEHP are detected only in whole body samples without detections in the associated fillet tissue and that BEHP is used in fishing lures and other fishing gear, in addition to other products, it is possible that the high concentrations of BEHP are due to sources of phthalates in the gut of the fish.

BEHP is not recommended as a COC in the FS because of the limited number of detected concentrations and the potential for sources of phthalates in whole body tissue (i.e., the gut) not related to sediment exposures.

2.1.5 PAHs

Carcinogenic PAHs, benzo(a)anthracene, benzo(a)pyrene, and dibenzo(a,h)anthracene, resulted in cancer risk levels greater than 1 x 10^{-6} for fish consumption. Figure 15 displays the cancer risk estimates for consumption of total carcinogenic PAHs in resident fish tissue by an adult non-tribal fisher. Cancer risk estimates from carcinogenic PAHs for fish consumption did not exceed 1 x 10^{-4}. For the adult non-tribal fish consumption scenario, the maximum cancer risk estimate for total carcinogenic PAHs was 2 x 10^{-5} (smallmouth bass fillet tissue collected at RM 5 and RM 8). Carcinogenic PAHs are not evaluated for noncancer hazards.

Cancer risk estimates for total carcinogenic PAH exceeded 1 x 10^{-6} for all three ingestion rates for consumption of smallmouth bass and for only ingestion rates of 73 g/day and 142 g/day for consumption of common carp. For consumption of smallmouth bass, cancer risk estimates for total carcinogenic PAHs exceeded 1 x 10^{-6} based on four individual RM segments and Study Area-wide exposures. For consumption of common carp, cancer risk estimates for total carcinogenic PAHs exceeded 1×10^{-6} based on two fishing zones and Study Area wide exposures.

PAHs account for less than 1% of the cumulative cancer risks for the exposure areas for which carcinogenic PAHs were detected. Carcinogenic PAHs are not recommended as COCs for the fish consumption pathway in the FS because of the low relative contribution to the cumulative risks.

2.1.6 Hexachlorobenzene

Hexachlorobenzene resulted in cancer risk estimates exceeding 1×10^{-6} for consumption of smallmouth bass, common carp, and whole body black crappie. Figure 16 displays the cancer risk estimates for consumption of hexachlorobenzene in fish tissue by an adult non-tribal fisher. With the exception of a single common carp fillet sample, the cancer risk estimates for hexachlorobenzene did not exceed 1×10^{-5}. In whole body smallmouth bass samples, the risks ranged from 2×10^{-6} to 7×10^{-6} at the ingestion rate of 142 g/day, indicating that concentrations did not vary significantly throughout the Study Area (risks for fillet consumption did not exceed 1×10^{-6} for smallmouth bass). In whole body carp, the risks ranged from 3×10^{-6} to 6×10^{-6} at the ingestion rate of 142 g/day. In the one sample where hexachlorobenzene resulted in cancer risks greater than 1×10^{-5}, hexachlorobenzene contributed to less than 10 percent of the cumulative risk for that sample (carp fillet from RM 6 to 9). On a Study Area-wide basis, hexachlorobenzene contributed to approximately 3 percent of the cumulative cancer risk for consumption of carp.

Hexachlorobenzene is not recommended as a COC in the FS because of the low relative contribution to the cumulative risks and the similar concentrations detected throughout the Study Area, with the exception of a single carp fillet sample.

2.1.7 Pesticides

Seven pesticides were associated with cancer risk estimates exceeding 1×10^{-6}. Pesticides were not associated with cancer risk estimates exceeding 1×10^{-4}. Three of the seven pesticides were also associated with HQs exceeding 1.

2.1.7.1 Aldrin

Aldrin was associated with only slight exceedances of the point of departure cancer risk level of 1×10^{-6}. Figure 17 displays the cancer risk estimates for consumption of aldrin in fish tissue by an adult non-tribal fisher. The maximum cancer risk estimate for aldrin in fish tissue was 2×10^{-6}. Exceedance of the 1×10^{-6} cancer risk level was only associated with the ingestion rate of 142 g/day for consumption of common carp. Ingestion rates less than 142 g/day or ingestion of other fish species did not result in risks greater than 1×10^{-6}.

Aldrin was reported as not detected for 40 percent of the EPCs for whole body and fillet common carp tissue and contributed to only approximately 0.01% to the total Study Area-wide risk for the whole body common carp diet. Aldrin was detected in smallmouth bass tissue though at concentrations associated with cancer risk estimates below 1×10^{-6}. Aldrin was not detected in whole body or fillet tissue for the resident species black crappie or brown bullhead.

Aldrin is not recommended as a COC in the FS because of the low frequency of detections in fish tissue, the low frequency of exceedance of the cancer risk of 1×10^{-6}, and the low magnitude the cancer risk estimates.

2.1.7.2 Dieldrin

Dieldrin resulted in exceedances cancer risks exceeding 1×10^{-6} based on consumption of all fish species (smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and on a localized and Study Area-wide basis. Figure 18 displays the cancer risk estimates for consumption of dieldrin in fish tissue by an adult non-tribal fisher. The maximum cancer risk estimate (1×10^{-4}) was associated with consumption of smallmouth bass fillet tissue collected at RM 8. Risks from dieldrin do not vary widely throughout the Study Area, suggesting a ubiquitous contribution of dieldrin that is not associated with a localized source.

Dieldrin was associated with exceedances of the 1×10^{-6} cancer risk level for all fish species; however, dieldrin was not detected in all fish tissue samples analyzed. For the multi-species whole body tissue diet, dieldrin contributes to less than one percent of the Study Area-wide cancer risk from fish consumption.

Dieldrin is not recommended as a COC in the FS because the magnitude of cancer risk estimates for the fish consumption is low and because dieldrin contributes to less than one percent of the cumulative cancer risk estimates for fish consumption.

2.1.7.3 Heptachlor Epoxide

Heptachlor epoxide resulted in only a slight exceedance of the cancer risk level of 1×10^{-6} based on only the 142 g/day ingestion rate for consumption of whole body common carp for one fishing zone (RM 0 to RM 4). The maximum cancer risk estimate was 2×10^{-6}. For this fishing zone, heptachlor epoxide contributes to 0.1% of cumulative risk from consuming whole body common carp. Figure 19 displays the cancer risk estimates for consumption of heptachlor epoxide in fish tissue by an adult non-tribal fisher. Heptachlor epoxide was reported as detected in the majority of smallmouth bass and common carp tissue samples analyzed, but was not detected in brown bullhead or black crappie tissue samples.

Heptachlor epoxide is not recommended as a COC in the FS because of the low frequency of detections in fish tissue, the low frequency of the cancer risk exceedance of 1×10^{-6}, and the low magnitude of the exceedance.

2.1.7.4 Total Chlordane

Total chlordane resulted in cancer risk estimates exceeding 1 x 10^{-6} for consumption of all fish species (smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and on a localized and Study Area-wide basis. Total chlordane was detected in the majority of composite fish tissue samples analyzed. Figure 20 displays the cancer risk estimates for consumption of total chlordane in fish tissue by an adult non-tribal fisher. The maximum cancer risk estimate for consumption of total chlordane in fish tissue by an adult non-tribal fisher was 2 x 10^{-5}, based on consumption of whole body brown bullhead tissue at an ingestion rate of 142 grams per day, both for fishing zone RM 3 to 6 and on a Study Area-wide basis. Total chlordane contributed to only approximately 2% of the cumulative cancer risk for consuming whole body brown bullhead tissue collected at fishing zone RM 3 to 6.

Total chlordane is not recommended as a COC in the FS because of the low contribution to the cumulative cancer risk estimates.

2.1.7.5 Total DDD

Total DDD resulted in cancer risk estimates exceeding 1 x 10^{-6} based on consumption of all fish species (smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and on a localized and Study Area-wide basis. Figure 21 displays the cancer risk estimates for consumption of total DDD in fish tissue by an adult non-tribal fisher. The maximum cancer risk estimate for total DDD (1 x 10^{-4}) was associated with consumption of whole body smallmouth bass tissue collected at RM 7. This risk level falls within EPA's target risk range of 1 x 10^{-6} to 1 x 10^{-4}. In addition, total DDD contributed to less than 1% of the total Study Area-wide cancer risk for whole body smallmouth bass. In the case of its highest risk in RM 7, total DDD contributed approximately 1% of the cumulative cancer risk.

Total DDD resulted in slight exceedances of a HQ of 1 based on consumption of whole body smallmouth bass tissue (RM 7) and whole body and fillet common carp tissue (fishing zone RM 4 to 8). The maximum HQ estimate (4) was based on consumption of whole body smallmouth bass tissue by a child non-tribal fisher at the ingestion rate of 60 g/day at RM 7. Though total DDD resulted in HQs greater than 1, the relative magnitude of exceedance was low. In addition, the relative contribution of total DDD to total noncancer hazard was less than 1% on both a Study Area-wide basis and at RM 7. Figure 22 displays the noncancer hazard estimates for consumption of total DDD in fish tissue by a non-tribal child.

Total DDD is recommended as a fish consumption-based COC in the FS as part of total DDx. At RM 7, total DDx has a maximum cancer risk of 3 x 10^{-4} and a noncancer hazard above 1. While total DDx is recommended as a COC on a localized basis, total DDx has a low contribution (i.e., less than 1%) to the cumulative cancer risk estimates and noncancer hazards on a Study Area-wide basis and only contributes approximately 3% to the total risks in RM 7.

2.1.7.6 Total DDE

Total DDE resulted in cancer risk estimates exceeding 1 x 10^{-6} based on consumption of all fish species (smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and on a localized and Study Area-wide basis. Figure 23 displays the cancer risk estimates for consumption of total DDE in fish tissue by an adult non-tribal fisher. The maximum cancer risk estimate for total DDE (1 x 10^{-4}) was associated with consumption of whole body smallmouth bass tissue collected at RM 7. This risk level falls within EPA's target risk range of 1 x 10^{-6} to 1 x 10^{-4}. In addition, total DDE contributed to less than 1% of the total Study Area-wide cancer risk for whole body smallmouth bass. In the case of its highest risk in RM 7, total DDE contributed approximately 1% of the cumulative cancer risk.

Total DDE resulted in slight exceedances of a HQ of 1 for consumption of whole body smallmouth bass tissue (for RM 7 and RM 8) and common carp tissue (for fishing zones RM 4 to 8 [whole body and fillet] and RM 3 to 6 [whole body only]). The maximum HQ estimate (3) was based on consumption of whole body smallmouth bass tissue (for RM 7) or whole body common carp tissue (for fishing zone RM 4 to 8) by a child non-tribal fisher at the ingestion rate of 60 g/day. Though total DDE resulted in HQs greater than 1, the relative magnitude of exceedance was low. In addition, the relative contribution of total DDE to total non-cancer hazard was less than 1% on both a Study Area-wide basis and on a river-mile specific basis. Figure 24 displays the non-cancer hazard estimates for consumption of total DDE in fish tissue by a non-tribal child.

Total DDE is recommended as a fish consumption-based COC in the FS as part of total DDx. At RM 7, total DDx has a maximum cancer risk of 3 x 10^{-4} and a noncancer hazard above 1. While total DDx is recommended as a COC on a localized basis, total DDx has a low contribution (i.e., less than 1%) to the cumulative cancer risk estimates and noncancer hazards on a Study Area-wide basis and only contributes approximately 3% to the total risks in RM 7.

2.1.7.7 Total DDT

Total DDT resulted in cancer risk estimates exceeding 1 x 10^{-6} based on consumption of all fish species (smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and on a localized and Study Area wide basis. Figure 25 displays the cancer risk estimates for consumption of total DDT in fish tissue by an adult non-tribal fisher. The maximum cancer risk estimate for total DDT (1 x 10^{-4}) was associated with consumption of whole body smallmouth bass tissue collected at RM 7. This risk level falls within EPA's target risk range of 1 x 10^{-6} to 1 x 10^{-4}. In addition, total DDT contributed to less than 1% of the total Study Area-wide cancer risk for whole body smallmouth bass. In the case of its highest risk in RM 7, total DDT only contributed approximately 1% of the cumulative cancer risk.

Total DDT resulted in slight exceedances of a HQ of 1 for consumption of whole body smallmouth bass tissue (for RM 7). The maximum HQ estimate was 3 based on consumption of whole body smallmouth bass tissue (for RM 7) by a child non-tribal fisher at the ingestion rate of 60 g/day. Though total DDT resulted in HQs greater than 1, the relative magnitude of exceedance was low. In addition, the relative contribution of total DDT to total non-cancer hazard was less than 1% on both a Study Area-wide basis and at RM 7. Figure 26 displays the non-cancer hazard estimates for consumption of total DDT in fish tissue by a non-tribal child.

Total DDT is recommended as a fish consumption-based COC in the FS as part of total DDx. At RM 7, total DDx has a maximum cancer risk of 3×10^{-4} and a noncancer hazard above 1. While total DDx is recommended as a COC on a localized basis, total DDx has a low contribution (i.e., less than 1%) to the cumulative cancer risk estimates and noncancer hazards on a Study Area-wide basis and only contributes approximately 3% to the total risks in RM 7.

2.1.8 PBDEs

PBDEs resulted in a HQ greater than 1 for consumption of whole body carp and whole body smallmouth bass. Cancer risks were not calculated for tissue ingestion scenarios because carcinogenic PBDE congeners were not detected in the tissue samples collected.

The highest HQ of 4 occurred at RM 4 from the consumption of smallmouth bass whole body tissue by an child with a 60 g/day ingestion rate, using exposure point concentrations equaling the maximum detected concentrations for the exposure area (due to limited sample size). HQs were above 1 for adult consumption of carp and smallmouth bass only at the 142 g/day consumption rate, and for child consumption of carp and smallmouth bass at both the 60 g/day and 31 g/day consumption rates. HQs from exposure to PBDEs in smallmouth bass and common carp whole body tissue ranged from 0.9 to 2 and from 1 to 2, respectively, for the maximum exposure point concentrations at the ingestion rate of 142 g/day, indicating that concentrations in both smallmouth bass and carp are similar throughout the Study Area.

PBDEs are flame retardants that leach from products with residential, commercial, and industrial uses. As a result, they are ubiquitous in the environment. PBDEs have been detected in fish tissue collected from the Columbia and Willamette River basins. In 2008, DEQ collected smallmouth bass, largemouth bass, and northern pikeminnow as part of the Willamette Basin Toxics Monitoring Project (DEQ 2008). The fish were collected at five locations at the Willamette River (RM 50 to RM 180), one location at the Multnomah Channel near St. Helens, one location at the Clackamas River, and one location at the Tualatin River. The fish samples were analyzed as composite tissue samples of fillets with skin removed. In 2006, Washington Department of Ecology (WDOE 2006) collected targeted game fish species from lakes and rivers as part of the PBDE Statewide Survey.

The PBDE congeners that were evaluated in the BHHRA, BDE 47 (2,2',4,4'-Tetrabromodiphenyl ether), BDE 99 (2,2',4,4',5-Pentabromodiphenyl ether), and BDE

153 (2,2',4,4',5,5'-Hexabromodiphenyl ether), were compared with the congener data from the DEQ and WDOE studies. The comparison of PBDE tissue concentrations is provided in Table 9. BDE 99 and BDE 153 concentrations detected in fish collected from Portland Harbor are similar to or less than BDE 99 and BDE 153 concentrations reported in the regional DEQ and WDOE fish tissue datasets (DEQ 2010 and WDOE 2006). For BDE 47, the fish tissue concentrations detected in smallmouth bass collected from Portland Harbor were similar to concentrations reported in the DEQ fish tissue dataset (Willamette River Watershed) and WDOE fish tissue dataset (Columbia River and Yakima River) evaluated for this memorandum. BDE 47 concentrations detected in common carp collected from Portland Harbor were up to five times greater than BDE 47 concentrations detected in other fish species collected by the Lower Willamette Group (LWG), DEQ, and WDOE. However, the lipid content in carp fillet tissue is higher than other species, which may result in higher PBDE concentrations in the fillet tissue. The concentrations in whole body smallmouth bass and common carp in Portland Harbor are similar. Fish collected from the Spokane River, which is considered a major source of PBDEs by WDOE, contained elevated PBDE concentrations respective to the Portland Harbor data set, the DEQ Willamette River Watershed dataset, and the WDOE dataset for the Columbia River and Yakima River.

Because of the ubiquitous nature of PBDEs, the similar concentrations throughout the Study Area, and because the concentrations of PBDEs detected in fish collected from Portland Harbor are similar to concentrations detected at other locations in the Columbia and Willamette Rivers, PBDEs are not recommended as a COC in the FS.

2.2 SHELLFISH CONSUMPTION

For shellfish consumption, seventeen chemicals resulted in exceedances of a cancer risk of 1×10^{-6} or HQ of 1, including PCBs, dioxins/furans, arsenic, PAHs, pentachlorophenol, and five pesticides. These chemicals and the respective risk management considerations used in recommending the COCs for shellfish consumption are summarized in Table 10. Risks from shellfish consumption are based on crayfish and clam tissue data.

For purposes of comparing cancer risks and noncancer hazards from individual chemicals across different species, the risk estimates for the non-tribal adult shellfish consumption scenario were used because it was the only shellfish consumption scenario evaluated for all chemicals in the BHHRA. Child receptors were not evaluated for shellfish consumption. The breastfeeding infant of a non-tribal adult shellfish consumer resulted in the highest noncancer hazards but was only evaluated for the bioaccumulative chemicals for which infant risk adjustment factors have been developed in DEQ guidance. These are: PCBs, dioxins/furans, and total DDx. In addition, infant risk from exposure to PBDEs in breastmilk was evaluated. While the magnitude of risk would change for the breastfeeding infant, the relative risks from the different species and ingestion rates would be the same.

2.2.1 PCBs

Total PCBs resulted in cancer risk estimates exceeding 1 x 10^{-4} and/or HQs exceeding 1 for shellfish consumption. Total PCBs resulted in cancer risk estimates exceeding 10^{-6} for all of the clam consumption exposure scenarios: depurated and undepurated samples, both ingestion rates of 18 g/day and 3.3 g/day, 95% UCL and mean EPCs, and both localized and Study-Area wide exposures. Figures 27 and 28 present the cancer risk estimates and noncancer hazard quotients, respectively, for total PCBs for consumption of shellfish by an adult non-tribal consumer. Total PCBs resulted in cancer risk estimates exceeding 1 x 10^{-4} at two locations (RM 6E and RM 11E) based on consumption of undepurated clams at the ingestion rate of 18 g/day. Total PCBs resulted in a maximum noncancer HQ of 30 at RM 6E for consumption of undepurated clams at the ingestion rate of 18 g/day.

Total PCB TEQ resulted in cancer risk estimates exceeding the target cancer risk level of 1 x 10^{-6} and/or HQs exceeding 1 for shellfish consumption. Figures 29 and 30 present the cancer risk estimates and noncancer hazard quotients, respectively, for PCB TEQ for consumption of shellfish by an adult non-tribal consumer. PCB TEQ resulted in cancer risk estimates exceeding the target risk level of 1 x 10^{-6} for all of the clam consumption exposure scenarios: depurated and undepurated samples, ingestion rates of 18 g/day and 3.3 g/day, 95% UCL and mean EPCs, and both localized and Study Area-wide exposures. Total PCBs TEQ resulted in a maximum cancer risk estimates of 1 x 10^{-4}, based on consumption of undepurated clams for station RM 6E.

Collectively, total PCBs and PCB TEQ contributed to approximately 44 percent of the cumulative cancer risk for the clam consumption scenario, based on undepurated clam samples and Study Area-wide exposure. Collectively, total PCBs and PCB TEQ contributed to approximately 52 percent of the cumulative cancer risk for the crayfish consumption scenario, based on Study Area wide exposures.

PCBs resulted in risk estimates that exceeded a cancer risk of 1 x 10^{-4} and/or HQ of 1 for both localized and Study Area-wide exposures for shellfish consumption. PCBs are recommended as a COC for the shellfish consumption pathway because of the magnitude of the risks and relative contribution to the cumulative risks. However, based on the magnitude of risks from PCBs for fish consumption relative to shellfish consumption, the evaluation of PCBs as a COC for the fish consumption pathway in the FS will address the shellfish consumption pathway as well.

2.2.2 Dioxins/Furans

Total dioxin TEQ resulted in cancer risk estimates exceeding 1 x 10^{-6} for consumption of both clams and crayfish, for both localized and Study Area-wide exposures, both 95% UCL and mean EPCs, and for both ingestion rates. Figures 31 and 32 present the cancer risk and noncancer hazard estimates, respectively, for total dioxin TEQ for consumption of shellfish by an adult non-tribal consumer. Total dioxin TEQ was detected in all of the

39 depurated and undepurated composite clam tissue samples analyzed and all of the 14 composite crayfish tissue samples analyzed.

For clam consumption, the highest total dioxin TEQ cancer risk estimate (8 x 10^{-5}) and HQ (1) were associated with a composite undepurated clam sample collected at RM 7W. Total dioxin TEQ contributed to only approximately 9 percent and 4 percent of the cumulative cancer risk estimate associated with Study Area-wide EPCs for undepurated and depurated clam tissue, respectively.

For crayfish consumption, the highest total dioxin TEQ cancer risk estimate (3 x 10^{-4}) and HQ (5) were associated with a composite crayfish sample collected at RM 7 (Station 07R006). This was the only sample location associated with a cancer risk estimate greater than 1 x 10^{-4}. At Station 07R006, total dioxin TEQ contributed to approximately 91 percent of the cumulative cancer risk. Total dioxin TEQ contributed to approximately 39 percent of the cumulative cancer risk estimate associated with Study Area-wide EPCs for crayfish tissue.

Dioxin/furans are recommended as a COC for the shellfish consumption pathway because of the magnitude of the risks at RM 7. However, based on the magnitude of risks from dioxins/furans for fish consumption relative to shellfish consumption, the evaluation of dioxins/furans as a COC for the fish consumption pathway in the FS will address the shellfish consumption pathway as well.

2.2.3 Arsenic

Arsenic resulted in cancer risk estimates that exceeded 1 x 10^{-6} based on consumption of both clams and crayfish, at both ingestion rates, and for localized and Study Area-wide exposures. Figure 33 presents the cancer risk estimates for arsenic for consumption of shellfish by an adult non-tribal consumer. No cancer risk estimates for ingestion of arsenic in shellfish tissue exceeded 1 x 10^{-4}.

Arsenic was detected in 31 of the 32 composite crayfish samples analyzed and all 41 of the depurated and undepurated composite clam tissue samples analyzed. There was little variability in the arsenic concentrations in clams or crayfish, resulting in a range of cancer risk estimates within a factor of 2 throughout the Study Area. The cancer risk estimates for consumption of arsenic in clam tissue ranged from 1 x 10^{-5} to 2 x 10^{-5} for undepurated and depurated clams, based on the highest ingestion rate of 18 g/day. The cancer risk estimates for consumption of arsenic in crayfish tissue ranged from 4 x 10^{-6} to 8 x 10^{-6}, based on the highest ingestion rate of 18 g/day. The small level of variability within arsenic concentrations in clam and crayfish tissue may be indicative that the tissue concentrations are in part due to naturally occurring background concentrations of arsenic in surface water and sediment.

Arsenic is not recommended as a COC for the shellfish consumption pathway in the FS based on the low relative magnitude of the risk exceedances and contribution to cumulative risk. Furthermore, arsenic concentrations in shellfish may be in part due to naturally occurring background concentrations.

2.2.4 PAHs

Carcinogenic PAHs resulted in cancer risk estimates that exceeded 1×10^{-6} for both clams and crayfish, at both ingestion rates, on both a localized and Study Area-wide scale. Figure 34 presents the cancer risk estimates for total carcinogenic PAHs for undepurated clam tissue, depurated clam tissue and crayfish tissue. The exposure scenario for consumption of undepurated clam tissue generally resulted in the highest cancer risk estimates for total carcinogenic PAHs.

One or more carcinogenic PAHs were detected in all of the clam tissue samples analyzed. Cancer risk estimates for total carcinogenic PAHs ranged from 2×10^{-7} to 5×10^{-4}, based on the ingestion rate of 18 g/day and 95% UCL EPCs. Cancer risk estimates for total carcinogenic PAHs exceeded 1×10^{-4} for the 18 g/day ingestion rate for undepurated clam tissue collected at locations RM 5W (5×10^{-4}) and RM 6W (5×10^{-4}). The cancer risk estimates for benzo(a)pyrene (4×10^{-4}) were the primary contributor to total carcinogenic PAH cancer risk at these two locations. Carcinogenic PAHs contributed to approximately 87 percent and 80 percent of the cumulative cancer risks at RM 5W and RM 6W, respectively. Carcinogenic PAHs contributed to approximately 35 percent and one percent of the cumulative cancer risk estimate associated with Study Area-wide EPCs for undepurated and depurated clam tissue, respectively. Depurated clam tissue samples were not collected at the locations of the highest undepurated clam tissue carcinogenic PAH EPCs (RM 5W and RM 6W), which may explain the lower cancer risk estimates for Study Area-wide exposures for consumption of depurated clam tissue relative to those undepurated clam tissue.

Carcinogenic PAHs were not detected in all of the crayfish composite samples analyzed; however, in some cases the detection limits were higher than concentrations that would lead to a cancer risk estimate of 1×10^{-6}. Benzo(a)pyrene resulted in a cancer risk estimate of 6×10^{-6} for the crayfish composite sample collected at Station CR06W at RM 6, based on the ingestion rate of 18 g/day. Benzo(a)pyrene was only detected in five of the 31 composite samples analyzed and no other benzo(a)pyrene concentrations resulted in a cancer risk estimate above 1×10^{-6}. Benzo(a)anthracene resulted in a cancer risk estimate of 6×10^{-6} for the crayfish composite sample collected at Station 06R004 at RM 6, based on the ingestion rate of 18 g/day. Benzo(a)anthracene was only detected in two of the 31 composite samples analyzed and no other benzo(a)anthracene concentrations resulted in a cancer risk estimate above 1×10^{-6}. Total carcinogenic PAHs resulted in cancer risk estimates between 1×10^{-6} and 1×10^{-4} for Stations CR06W and 06R004. Total carcinogenic PAHs contributed to approximately 22 and 15 percent of the cumulative cancer risk estimates at Stations CR06W and 06R004, respectively. No other individual PAH detections resulted in a cancer risk estimate above 1×10^{-6} based on consumption of crayfish tissue.

Carcinogenic PAHs are recommended as COCs for the shellfish consumption pathway in the FS because of the magnitude of the risk exceedances and relative contribution to cumulative risk for shellfish consumption. Carcinogenic PAHs are only recommended as a COC for clam consumption.

2.2.5 Pentachlorophenol

Pentachlorophenol was only detected in one shellfish sample, which was a crayfish composite sample collected near RM 8 (Station 08R003). The detection of pentachlorophenol in the crayfish composite sample collected at Station 08R003 resulted in a cancer risk estimate of 6×10^{-6}. Pentachlorophenol was associated with five percent of the cumulative cancer risk estimate for the composite crayfish sample collected at Station 08R003, and less than 1 percent of the cumulative cancer risk estimate for the Study Area-wide exposure.

Pentachlorophenol is not recommended as a COC in the FS because it was detected in only one of the 41 shellfish samples in which it was analyzed and has a low contribution to cumulative risk.

2.2.6 Pesticides

Aldrin, dieldrin, total DDD, total DDE, and total DDT were associated with one or more shellfish consumption exposure scenarios that resulted in a cancer risk estimate above 1×10^{-6} or a HQ exceeding 1. These pesticides were not associated with shellfish consumption scenarios that resulted in a cancer risk estimate above 1×10^{-4}.

2.2.6.1 Aldrin

Aldrin was detected in 39 of the 44 composite clam tissue samples analyzed. The majority of detected concentrations resulted in cancer risk estimates below 1×10^{-6}. No HQ estimates exceeded a HQ of 1. Figure 35 presents the cancer risk estimates for aldrin based on consumption of undepurated clam tissue, depurated clam tissue and crayfish tissue. Only one location, RM 8W, resulted in cancer risks that exceeded 1×10^{-6} for consumption of undepurated clam tissue (9×10^{-6} at the ingestion rate of 18 g/day and 2×10^{-6} at the ingestion rate of 3.3 g/day). Aldrin contributed to less than five percent of the cumulative cancer risk at that location and less than one percent of the cumulative cancer risk estimate for Study Area-wide exposure.

Aldrin was only detected in one of the 31 crayfish samples analyzed (CR08W near RM 8 W), which did not result in a cancer risk estimate above 1×10^{-6}. The detection limit for aldrin in crayfish tissue was elevated in 26 of the 30 samples reported as non-detect concentrations of aldrin. Aldrin would not result in a cancer risk above 1×10^{-6} if the EPC was equal to the elevated detection limits, with the exception of the non-detected concentration (Station 07R003) associated with a detection limit of 1 microgram per kilogram (μg/kg). An aldrin EPC of 1 μg/kg would result in a cancer risk estimate of 2×10^{-6}, only slightly above 1×10^{-6}.

Aldrin is not recommended as a COC in the FS because it resulted in cancer risk estimates above the target cancer risk of 1 x 10^{-6} at only one location and has a low contribution to cumulative risk for shellfish consumption.

2.2.6.2 Dieldrin

Dieldrin was detected in 41 of the 44 composite clam tissue samples analyzed. Dieldrin resulted in cancer risk estimates above 1 x 10^{-6} for ingestion of undepurated clam tissue for the 18 g/day ingestion rate only for ten individual exposure areas. Figure 36 presents the cancer risk estimates for dieldrin based on consumption of undepurated clam tissue, depurated clam tissue and crayfish tissue. Consumption of dieldrin in clam tissue did not result in HQs that exceeded the target HQ of 1. The maximum cancer risk estimate (5 x 10^{-6}) was associated with consumption of undepurated clam tissue from RM 8W. Dieldrin contributed to approximately two percent of the cumulative cancer risk at that location and to less than one percent of the cumulative cancer risk estimate associated with the Study Area-wide exposure.

Dieldrin was only detected in five of the 31 crayfish samples analyzed. The detected concentrations did not result in a cancer risk estimate above 1 x 10^{-6}. The detection limit for dieldrin in crayfish tissue was elevated in 26 of the 30 composite crayfish samples reported as non-detect concentrations of dieldrin. Dieldrin would not result in a cancer risk above 1 x 10^{-6} if the EPC was equal to the elevated detection limits, with the exception of the non-detected concentration (Station 07R003) associated with a detection limit of 1 µg/kg. A dieldrin EPC of 1 µg/kg would result in a cancer risk estimate of 2 x 10^{-6}, slightly above the target cancer risk level of 1 x 10^{-6}.

Dieldrin is not recommended as a COC in the FS because of the low magnitude and frequency of the cancer risk estimates above the target cancer risk of 1 x 10^{-6} and because dieldrin has a low contribution to cumulative risk for shellfish consumption.

2.2.6.3 Total DDD

Total DDD was detected in all of the 44 composite clam tissue samples analyzed. Total DDD resulted in cancer risk estimates above 1 x 10^{-6} for ingestion of undepurated clams for the 18 g/day ingestion rate only for two individual exposure areas. Figure 37 presents the cancer risk estimates for total DDD based on consumption of undepurated clam tissue, depurated clam tissue, and crayfish tissue. The maximum cancer risk estimate (5 x 10^{-6}) was associated with consumption of clam tissue (undepurated) from RM 6W and RM 7W. Total DDD contributed to approximately 3 percent of the cumulative cancer risk at RM 7W and to less than one percent of the cumulative cancer risk estimate at RM 6W and for the Study Area-wide exposure. Consumption of total DDD in clam tissue did not result in HQs that exceeded the target HQ of 1.

Total DDD was detected in ten of the 31 composite crayfish samples analyzed and the detection limits associated with the non-detected concentrations did not exceed the maximum detected concentration. Total DDD in crayfish tissue did not result in cancer risk estimates above 1 x 10^{-6} or HQs above 1.

Total DDD is not recommended as a COC for the shellfish consumption pathway in the FS because of the low magnitude and frequency of the cancer risk estimates above the target cancer risk of 1 x 10^{-6} and because total DDD has a low contribution to cumulative risk for shellfish consumption.

2.2.6.4 Total DDE

Total DDE was detected in all of the 44 composite clam tissue samples analyzed. Total DDE resulted in cancer risk estimates slightly above 1 x 10^{-6} for ingestion of clams (undepurated tissue) for the 18 g/day ingestion rate only for only three individual exposure areas (RM 6W, RM 7W, and RM 8W). Figure 38 presents the cancer risk estimates for total DDE based on consumption of undepurated clam tissue, depurated clam tissue and crayfish tissue. The maximum cancer risk estimate (3 x 10^{-6}) was associated with consumption of undepurated clam tissue from sampling locations near RM 7W and RM 8W. Total DDE contributed to approximately two percent of the cumulative cancer risk in RM 7W, one percent of the cumulative cancer risk in RM 8W, and less than one percent of the cumulative cancer risk estimate associated with the Study Area-wide exposure. Consumption of total DDE in clam tissue did not result in HQs that exceeded the target HQ of 1.

Total DDE was detected in all of the 31 composite crayfish samples analyzed. Total DDE resulted in one cancer risk estimate (2 x 10^{-6}) slightly above the target risk level of 10^{-6} for ingestion of crayfish at the 18 g/day ingestion rate only and for only one individual exposure area near RM 7 (Station 07R006). Total DDE in crayfish tissue did not result in HQs above 1.

Total DDE is not recommended as a COC for the shellfish consumption pathway in the FS because of the low magnitude and frequency of the cancer risk estimates above the target cancer risk of 1 x 10^{-6} and because total DDE has a low contribution to cumulative risk for shellfish consumption.

2.2.6.5 Total DDT

Total DDT was detected in 43 of the 44 composite clam tissue samples analyzed. Total DDT resulted in cancer risk estimates slightly above 1 x 10^{-6} for ingestion of clams (undepurated tissue) for the 18 g/day ingestion rate for only two individual exposure areas (RM 6W and RM 7W). Figure 39 presents the cancer risk estimates for total DDT based on consumption of undepurated clam tissue, depurated clam tissue and crayfish tissue. The maximum cancer risk estimate (3 x 10^{-6}) was associated with consumption of undepurated clam tissue from RM 7W. Total DDT contributed to approximately two percent of the cumulative cancer risk at this location and less than one percent of the cumulative cancer risk estimate associated with the Study Area-wide exposure.

Consumption of total DDT in clam tissue did not result in HQs that exceeded the target HQ of 1.

Total DDT was detected in twenty of the 31 composite crayfish samples analyzed and the detection limits associated with the non-detected concentrations did not exceed the maximum detected concentration. Total DDT in crayfish tissue did not result in cancer risk estimates above 1×10^{-6} or HQs above 1.

Total DDT is not recommended as a COC for the shellfish consumption pathway in the FS because of the low magnitude and frequency of the cancer risk estimates above the target cancer risk of 1×10^{-6} and because total DDT has a low contribution to cumulative risk for shellfish consumption.

2.3 DIRECT EXPOSURE TO IN-WATER SEDIMENT

For direct exposure to in-water sediment, PAHs (primarily benzo(a)pyrene), arsenic, PCBs, and dioxins/furans resulted in cancer risk estimates that exceeded 1×10^{-6}. These chemicals and the respective risk management considerations used in recommending the COCs for direct exposure to in-water sediment are summarized in Table 11. For the RME scenarios, cumulative cancer risks were greater than 1×10^{-6} but were below 1×10^{-4}, with the exception of cancer risks above 1×10^{-4} for in-water sediment by a tribal fisher at exposure areas RM 6W (due primarily to PAHs) and RM 7W (due primarily to dioxins/furans). Figure 40 presents the cancer risk estimates associated with direct exposure to in-water sediment by the tribal fisher for total PCBs, total PCB TEQ, total carcinogenic PAHs, total dioxin TEQ, and arsenic. HQ estimates exceeded 1 only for dioxins/furans for the tribal fisher at a single exposure area (RM 7W).

2.3.1 PCBs

PCBs resulted in exceedances of a cancer risk of 1×10^{-6} only for the tribal fisher scenario. For the tribal fisher scenario, PCBs resulted in cancer risk estimates that exceeded 1×10^{-6} for three localized exposure areas (RM 8.5W, RM 9W, and RM 11E) based on the RME EPCs only. The maximum cancer risk estimate for exposure to PCBs by a tribal fisher was 6×10^{-6} (RM 8.5W). PCBs did not result in HQs above 1 for any of the exposure scenarios. For the RME tribal fisher exposure scenario, total PCBs did not exceed 1×10^{-6} for the Study Area-wide cancer risk estimate and contributes to one percent of the cumulative cancer risk.

PCBs are not recommended as a COC in the FS for the in-water sediment exposure pathway based on the low magnitude of cancer risk estimates and the low contribution to cumulative cancer risks.

2.3.2 Dioxins/Furans

Dioxins/furans resulted in cancer risk estimates exceeding 1 x 10^{-6} for only one exposure area (RM 7W) for the in-water worker, high and low frequency fisher, and wet and dry suit diver scenarios. The tribal fisher cancer risk estimate based on the RME EPC for RM 7W (3 x 10^{-4}) exceeded 1 x 10^{-4}. For the RME tribal fisher exposure scenario, dioxins/furans contributed to approximately 48 percent of the Study Area-wide cancer risk estimate. The only CT scenario that resulted in cancer risk estimates above 1 x 10^{-6} was for the tribal fisher scenario and for only the RM 7W exposure area. Dioxins/furans resulted in an HQ of 2 for the tribal fisher exposure scenario.

For the in-water sediment exposure scenarios, incidental ingestion contributed to over 70 percent of the total cancer risk estimate for dioxins/furans. As noted previously, there is a high degree of uncertainty associated with the sediment ingestion rate. The RME tribal fisher scenario assumes that up to 2 pounds of sediment will be ingested over the exposure duration of 70 years.

Dioxin/furans are recommended as a COC in the FS for the in-water sediment exposure pathway based on the magnitude of cancer risk and the exceedance of 1 x 10^{-6} for multiple exposure scenarios at RM 7W.

2.3.3 Arsenic

Arsenic resulted in cancer risk estimates exceeding 1 x 10^{-6} for the tribal fisher and high frequency fisher scenarios only. For the tribal fisher scenario, cancer risk estimates above 1 x 10^{-6} ranged from 2 x 10^{-6} to 7 x 10^{-6} and were only associated with RME EPCs for twelve localized exposure areas. For the RME tribal fisher exposure scenario, arsenic contributed to approximately six percent of the Study Area-wide cancer risk estimate. Arsenic did not result in HQs above 1 for any of the in-water sediment exposure scenarios.

For the tribal fisher scenario, an arsenic EPC at the DEQ background level of 7 mg/kg (DEQ 2007) would result in a cancer risk estimate of 2 x 10^{-6}, indicating that the cancer risk estimates are in part due to background contributions.

Arsenic is not recommended as a COC in the FS for the in-water sediment exposure pathway because arsenic is a naturally occurring metal and cancer risks greater than 1 x 10^{-6} are attributed in part to background contributions.

2.3.4 PAHs

Carcinogenic PAHs result in exceedances of a cancer risk of 1 x 10^{-6} for the high and low frequency fisher, tribal fisher, and wet suit and dry suit diver in-water sediment exposure scenarios. Carcinogenic PAHs resulted in a slight exceedance of a cancer risk estimate of 1 x 10^{-4} at only one exposure area (RM 6W) and for only the RME tribal fisher exposure scenario. The maximum cancer risk estimate was 2 x 10^{-4}. For the RME tribal fisher exposure scenario, total carcinogenic PAHs contributed to approximately 43 percent of the Study Area-wide cancer risk estimate.

For the in-water sediment exposure scenarios, dermal contact contributed to approximately 60 percent of the total cancer risk estimate for total carcinogenic PAHs. As noted previously, the RME parameters for the dermal exposure pathway are associated with a high degree of uncertainty and were based on conservative assumptions that may overestimate actual risks. The in-water sediment exposure scenarios based on CT parameters only resulted in one exceedance of a cancer risk estimate of 1×10^{-6} (6×10^{-6} for RM 6W).

Carcinogenic PAHs are recommended as a COC in the FS for the in-water sediment exposure pathway due to the magnitude of cancer risk and the exceedance of 1×10^{-6} for multiple scenarios at RM 6W.

2.4 DIRECT EXPOSURE TO BEACH SEDIMENT

For direct exposure to beach sediment, PAHs (primarily benzo[a]pyrene) and arsenic resulted in exceedances of a cancer risk of 1×10^{-6}. These chemicals and the respective risk management considerations used in recommending the COCs for direct exposure to beach sediment are summarized in Table 12. The highest cancer risk estimates were associated with the dockside worker and tribal fisher scenario. Figure 41 presents the cancer risk estimates associated with direct exposure to beach sediment by the tribal fisher, for the chemicals total carcinogenic PAHs and arsenic. No chemicals resulted in exceedances of a HQ of 1.

2.4.1 Arsenic

Arsenic resulted in cancer risk estimates exceeding 1×10^{-6} for the adult and child beach recreational user, high and low frequency fisher, and tribal fisher scenarios. The maximum arsenic cancer risk estimate was 2×10^{-5}, associated with the tribal fisher RME scenario. For the child recreational beach user and the tribal fisher exposure scenarios, cancer risk estimates exceeded 1×10^{-6} for all of the beaches.

For beach sediment, the exposure point concentrations ranged from 0.7 mg/kg to 9.9 mg/kg and are consistent with the default background soil concentration for arsenic of 7 mg/kg used by DEQ (DEQ 2007). For the RM E tribal fisher and adult and child recreational beach user, excluding background arsenic concentrations, exposure to beach sediment results in risks exceeding 1×10^{-6} from exposure to arsenic at only one beach location (06B030). Direct contact with carcinogenic PAHs in beach sediment also poses risks exceeding 1×10^{-6} at this location.

Arsenic is not recommended as a COC in the FS for the beach sediment exposure pathway because arsenic is a naturally occurring metal and cancer risk estimates are attributed in large part to background contributions.

2.4.2 PAHs

Based on RME assumptions, total carcinogenic PAHs resulted in cancer risk estimates exceeding 1 x 10^{-6} for the dockside worker, adult and child beach recreational user, high and low frequency fisher, and tribal fisher scenarios. Based on CT exposure assumptions, total carcinogenic PAHs resulted in cancer risk estimates exceeding 1 x 10^{-6} for the only the dockside worker scenario and only for beach location 06B025. The transient beach user exposure scenario did not result in cancer risks above 1 x 10^{-6}. The maximum cancer risk estimate (9 x 10^{-5}) for direct contact with total carcinogenic PAHs in beach sediment was associated with the RME dockside worker scenario at beach location 06B025.

The majority of the beaches were not associated with cancer risk estimates exceeding 1 x 10^{-6} for direct exposure to carcinogenic PAHs. The RME dockside worker scenario resulted in carcinogenic PAHs cancer risk estimates that exceeded 1 x 10^{-6} at two of the eight beaches. The RME adult recreational beach user scenario resulted in carcinogenic PAHs cancer risk estimates that exceeded 1 x 10^{-6} at two of the 15 beaches. The RME child recreational beach user scenario resulted in carcinogenic PAHs cancer risk estimates that exceeded 1 x 10^{-6} at four of the 15 beaches. The RME tribal fisher scenario resulted in carcinogenic PAHs cancer risk estimates that exceeded 1 x 10^{-6} at eight of the 18 beaches. The RME high and low frequency fisher scenario resulted in carcinogenic PAHs cancer risk estimates that exceeded 1 x 10^{-6} at only 2 of the 18 beaches.

Over 65 percent of the cancer risk for direct contact with carcinogenic PAHs beach sediment scenarios is associated with dermal contact. There are multiple uncertainties associated with the dermal exposures pathway such as the skin surface area exposed, soil AFs, and soil absorption factor for PAHs.

Carcinogenic PAHs are not recommended as a COC in the FS for the beach sediment exposure pathway based on the uncertainties associated with the exposure parameters.

2.5 DIRECT EXPOSURE TO SURFACE WATER

For direct exposures to surface water, only carcinogenic PAHs resulted in a cancer risk estimate exceeding 1 x 10^{-6}. Direct exposure to carcinogenic PAHs in surface water by a wet suit diver and dry suit diver resulted in cancer risk estimates of 1 x 10^{-5} and 2 x 10^{-6}, respectively (primarily due to benzo(a)pyrene) and for only one exposure area (RM 6W). Direct contact with surface water by adult and child recreational beach users, or transients did not result in cancer risk estimates above 1 x 10^{-6}.

There is additional uncertainty associated with the chemical specific absorbed dose per event for dermal contact with surface water. This parameter was derived per EPA guidance (2004) using chemical-specific factors, but the dermal permeability coefficient (Kp) falls outside of the effective predictive domain (EPD) for a number of PAHs (including benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)anthracene).

EPA guidance (EPA 2004) states that "Although the methodology [for predicting the absorbed dose per event] can be used to predict dermal exposures and risk to contaminants in water outside the EPD, there appears to be greater uncertainty for these contaminants." The range of uncertainty associated with the Kp value can be several orders of magnitude. For instance, the predicted Kp value recommended by EPA (2004) for benzo(a)pyrene is 0.7 centimeters per hour (cm/hr), while the range of predicted Kp values presented by EPA (2004) is 0.024 cm/hr (95% lower confidence level) to 20 cm/hr (95% upper confidence level). This uncertainty could result in over-estimation or under-estimation of risk from exposure to surface water.

Carcinogenic PAHs in surface water are not recommended as COCs in the FS based on the limited spatial scale of the cancer risk exceedance and the high degree of uncertainty in the exposure assumptions.

3.0 SUMMARY OF RECOMMENDATIONS

EPA guidance for the role of risk assessment in remedy selection under CERCLA (EPA 1991) uses the general cancer risk range of 10^{-6} to 10^{-4} as a "target range" within which the EPA manages risk during the remedy selection. EPA has a preference to select remedies that are at the more protective end of the risk range; EPA also recognizes that site-specific information and analyses will be considered in the FS in order to make a final determination of protectiveness. Furthermore, if the cumulative cancer risk to an individual based on RME assumptions is less than 10^{-4} and the noncancer HQ is less than 1, remedial action generally is not warranted at a site (EPA 1991). DEQ guidance sets an acceptable cancer risk level of 1 x 10^{-6} for individual chemicals and 1 x 10^{-5} for cumulative cancer risks (OAR 340-122-0115). The development of risk management recommendations considered all contaminants and exposure scenarios exceeding a cancer risk of 1 x 10^{-6} or HQ of 1. However, the only exposure pathways in the BHHRA with cancer risks exceeding 1 x 10^{-4} or HQ greater than 1 are fish consumption, shellfish consumption, and direct exposure to in-water sediment.

The COCs and exposure pathways recommended to develop and evaluate remedial alternatives in the FS to be protective of human health are shown in Table 13 and summarized as follows:.

- For the fish consumption exposure pathway, PCBs, dioxin/furans, and total DDx are the chemicals recommended as COCs in the FS. PCBs and dioxin/furans are the primary contributors to the cumulative risk estimates. Although other chemicals were associated with cancer risk estimates above 1 x 10^{-6} and/or HQs greater than 1, there is low relative risk reduction in addressing these chemicals in the FS on a Study Area-wide basis.
- For the shellfish consumption exposure pathway, PCBs, dioxin/furans, and carcinogenic PAHs are recommended as COCs in the FS. Because PCBs and dioxins/furans will be addressed by the evaluation of the fish consumption pathway, clam consumption is the only shellfish consumption scenario recommended for the FS.
- For the in-water sediment exposure pathway, dioxin/furans and carcinogenic PAHs are recommended as COCs. Dioxin/furans were the primary contributor to risk in RM 7W. Carcinogenic PAHs were the primary contributor to risk in RM 6W.
- COCs are not recommended for any of the other exposure pathways evaluated in the BHHRA.

The BHHRA incorporated health protective assumptions in evaluating the risks to human health at the site, consistent with EPA guidance. The assumptions used in the BHHRA should be considered in the development and evaluation of remedies in the FS. While the remedial action objectives should be developed and applied consistent with assumptions used in the BHHRA and using target cancer risks and target noncancer hazard levels consistent with EPA's target levels under CERCLA, the uncertainties associated with the risk estimates need to be considered.

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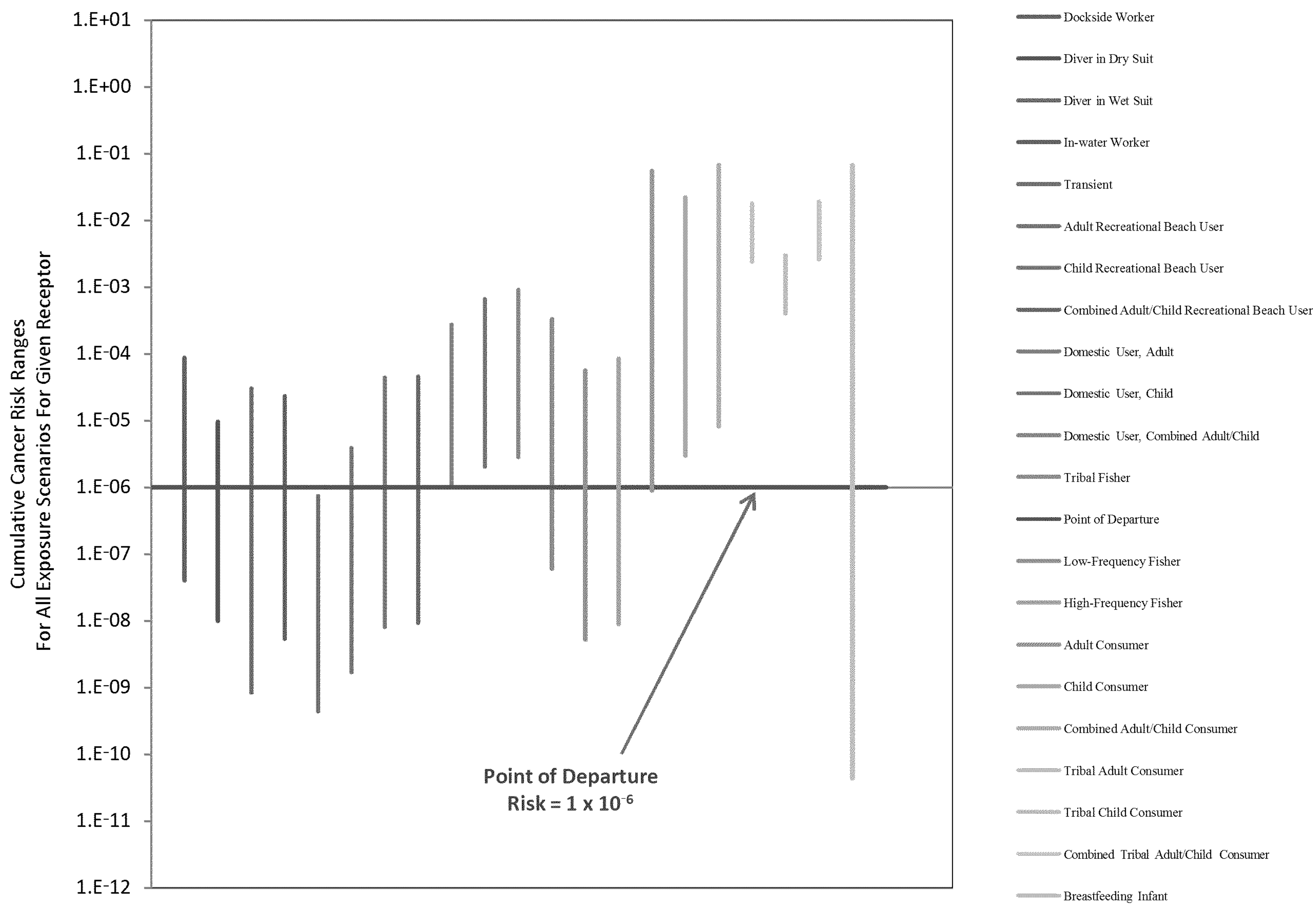

Figure 1
Ranges of Cumulative Cancer Risks for BHHRA Receptors

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

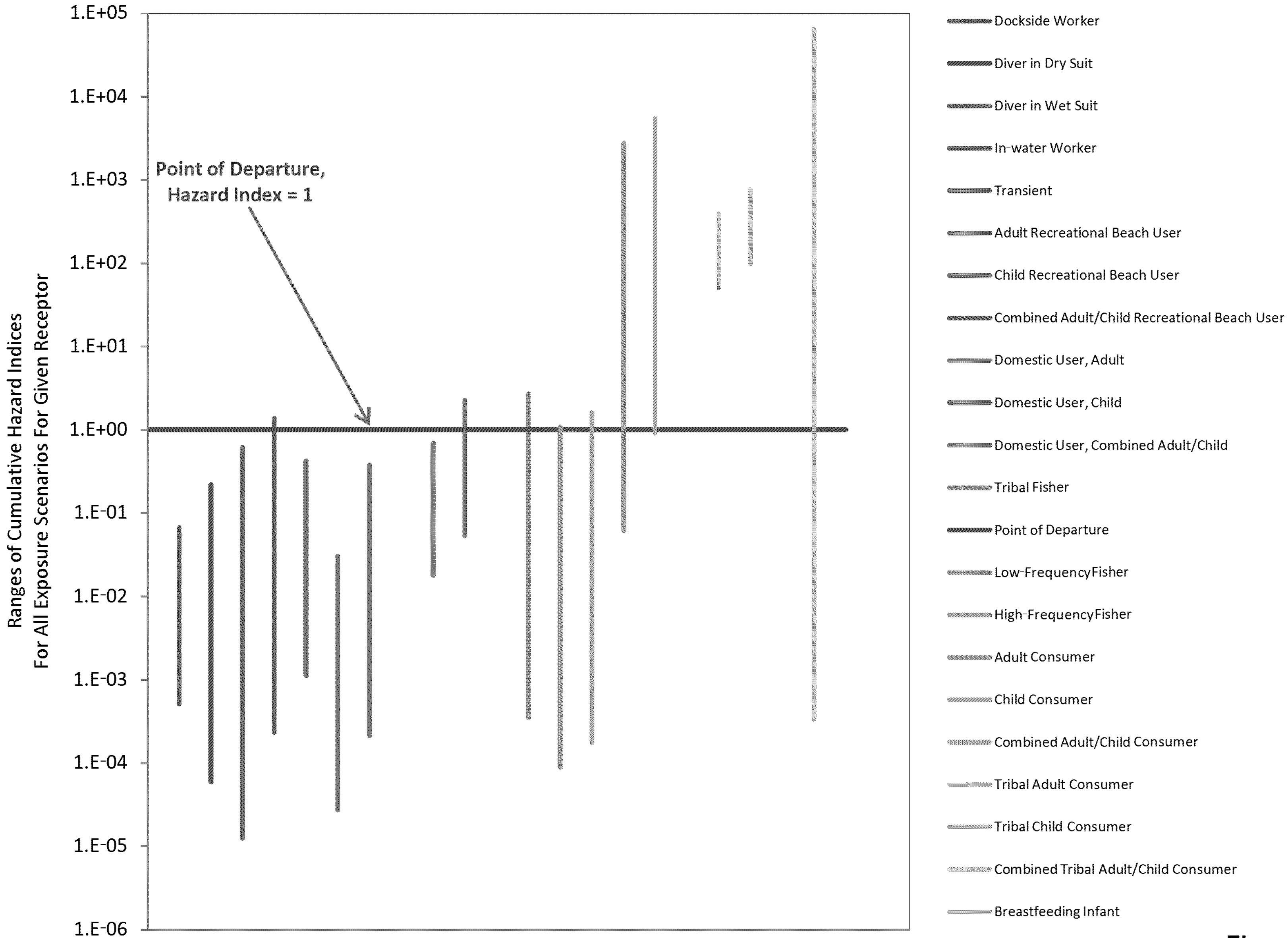

Figure 2
Ranges of Cumulative Hazard Indices for BHHRA Receptors

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

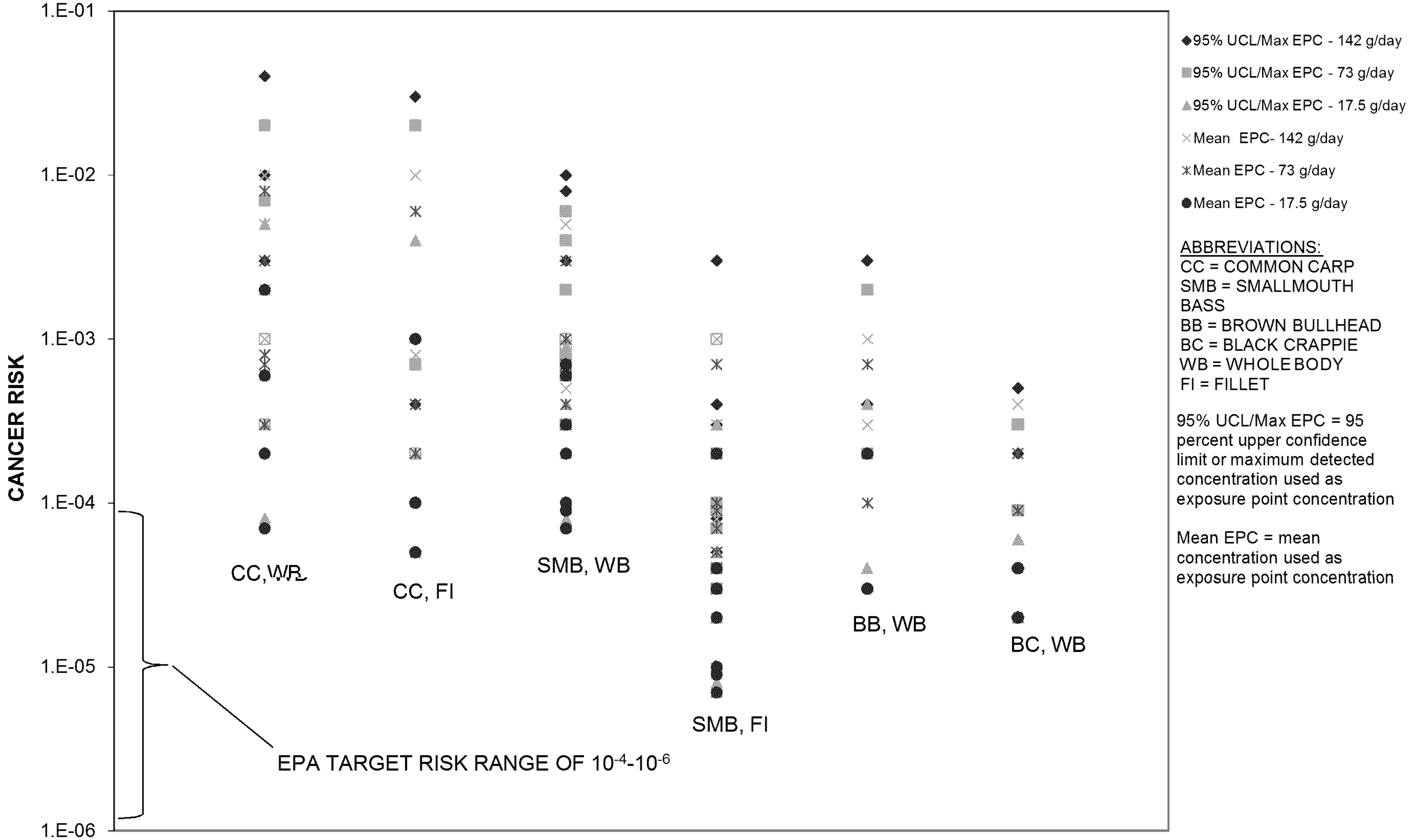

Figure 3
Non-Tribal Adult Cancer Risk From Total PCBs in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

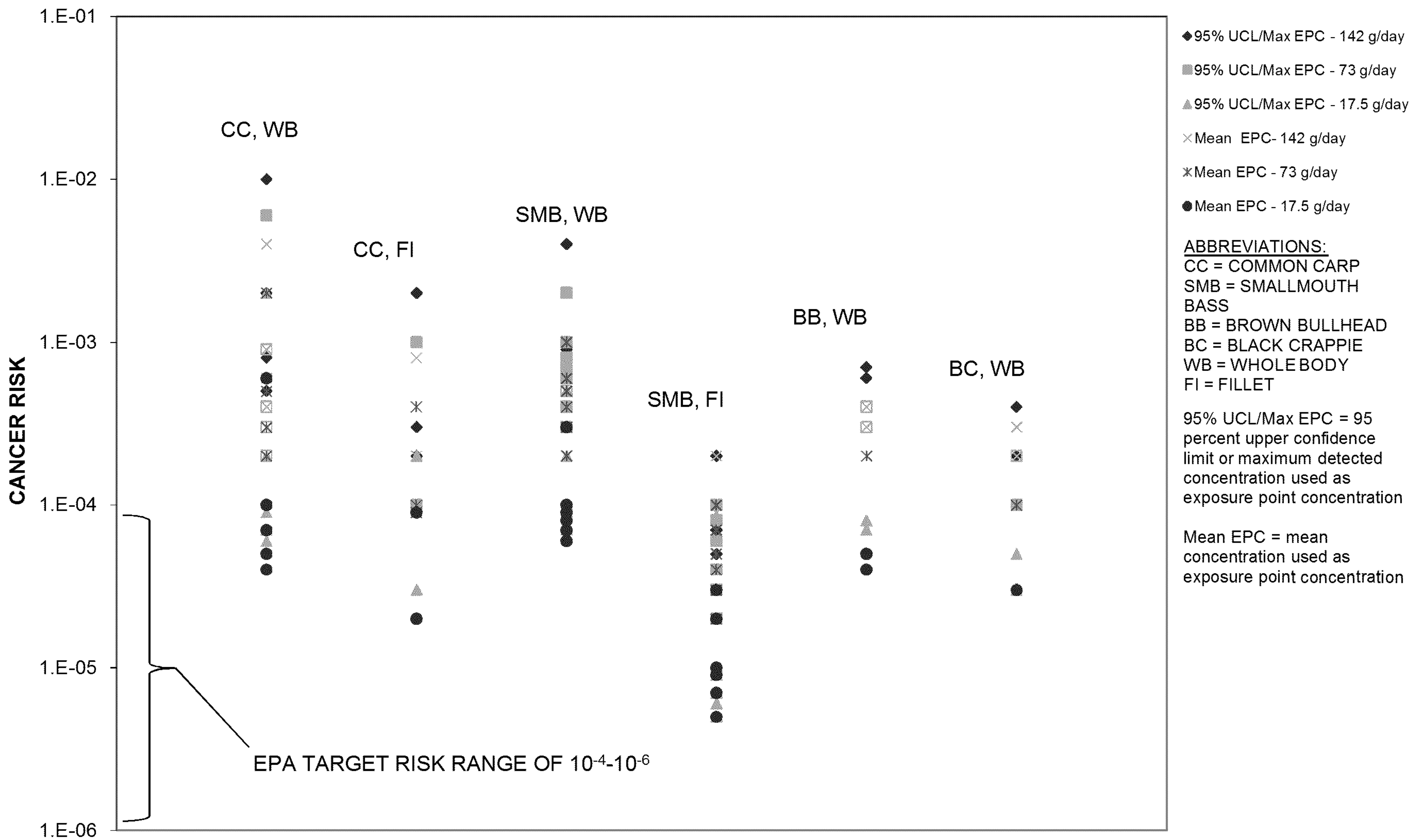

Figure 4
Non-Tribal Adult Cancer Risk From Total PCB TEQ in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

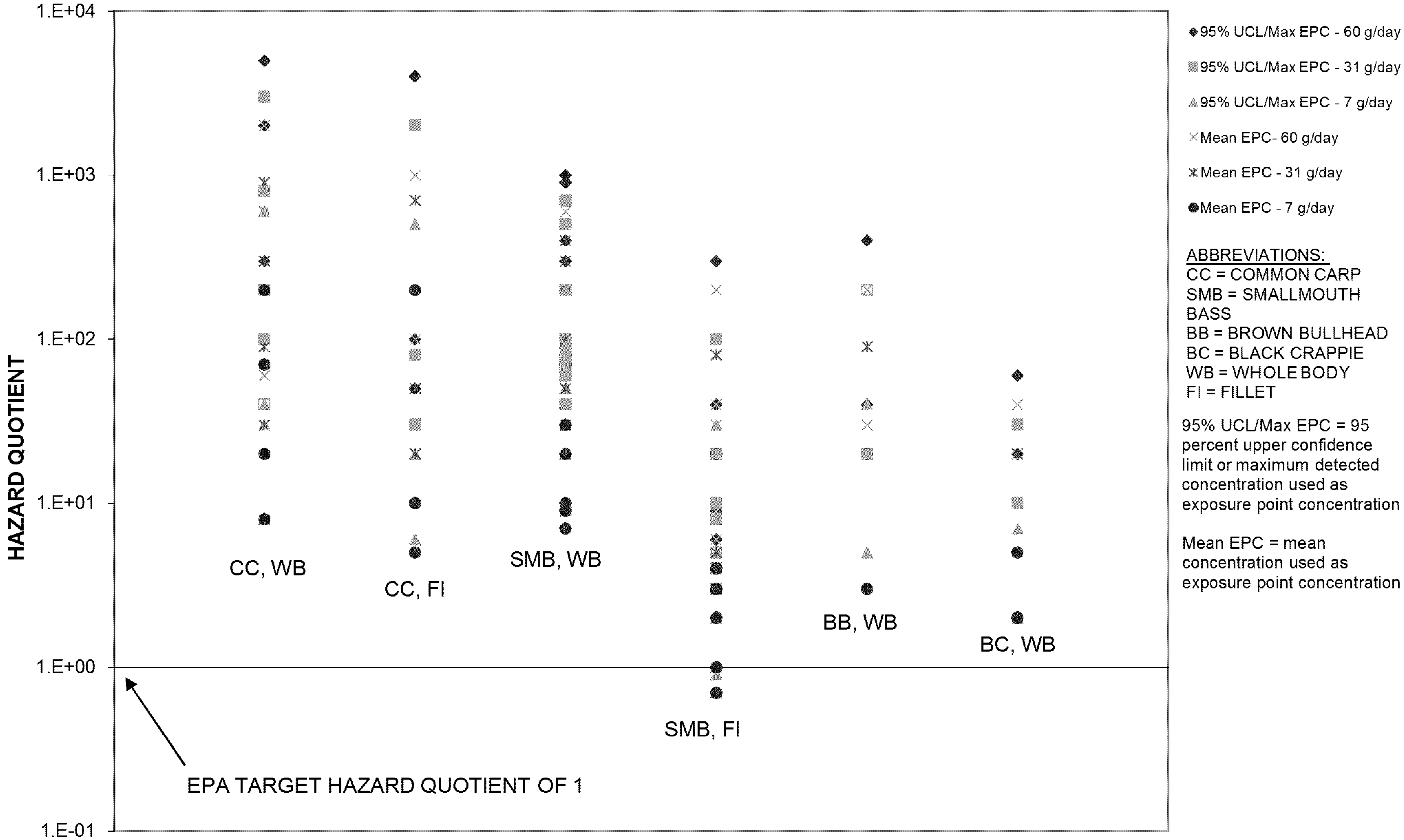

Figure 5
Non-Tribal Child Noncancer Hazard From Total PCBs in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

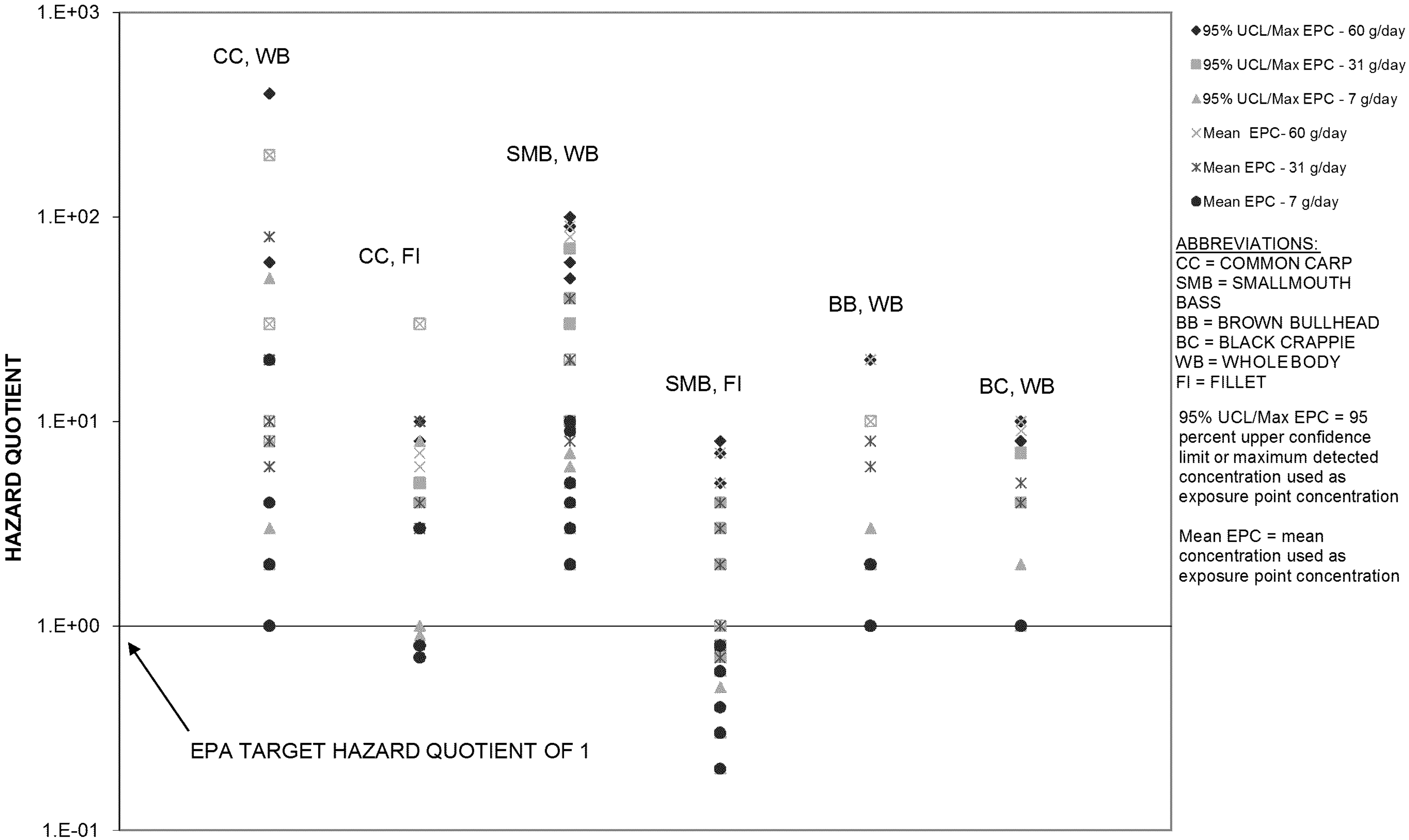

Figure 6
Non-Tribal Child Noncancer Hazard From Total PCB TEQ in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

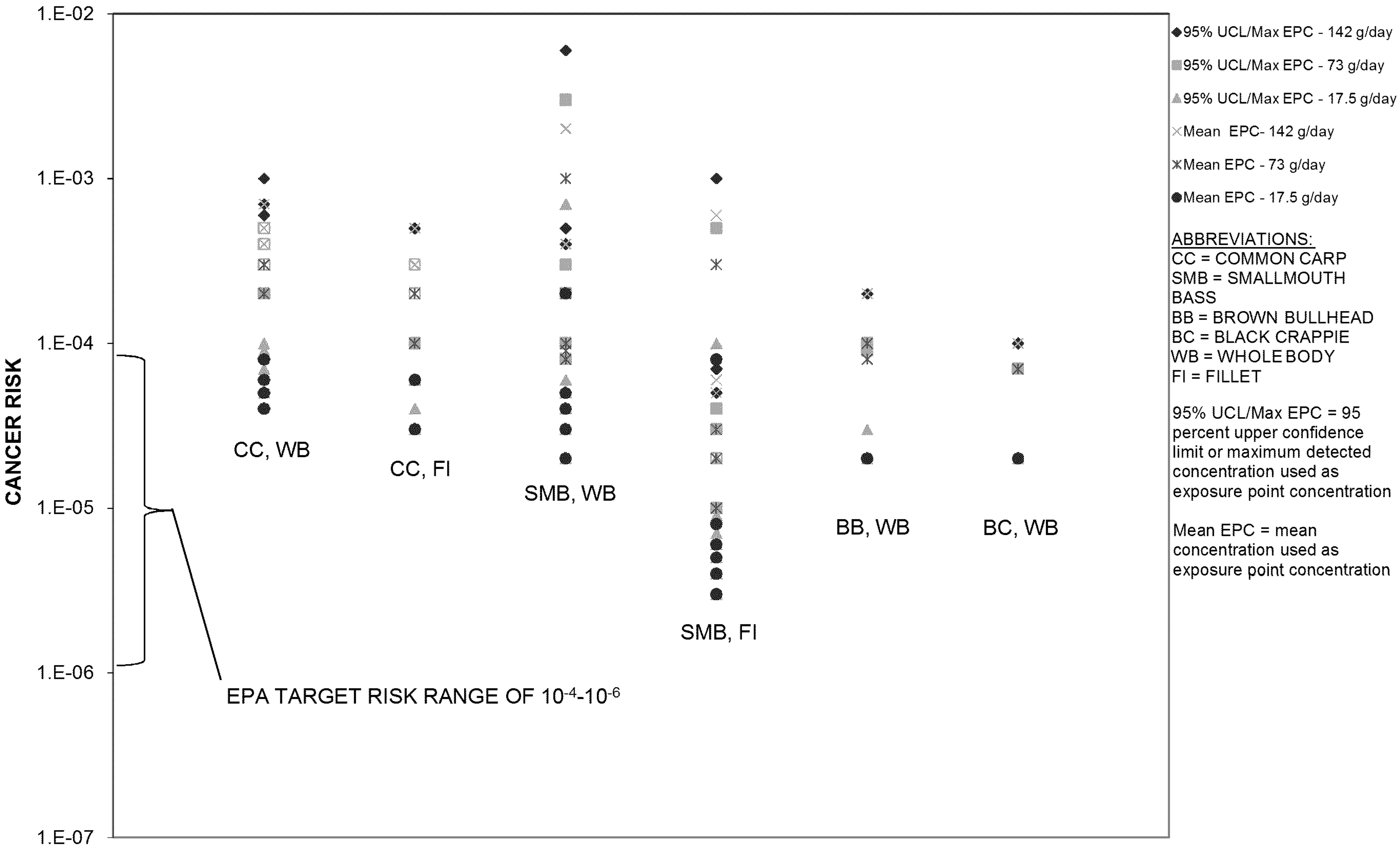

Figure 7
Non-Tribal Adult Cancer Risk From Total Dioxin TEQ in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

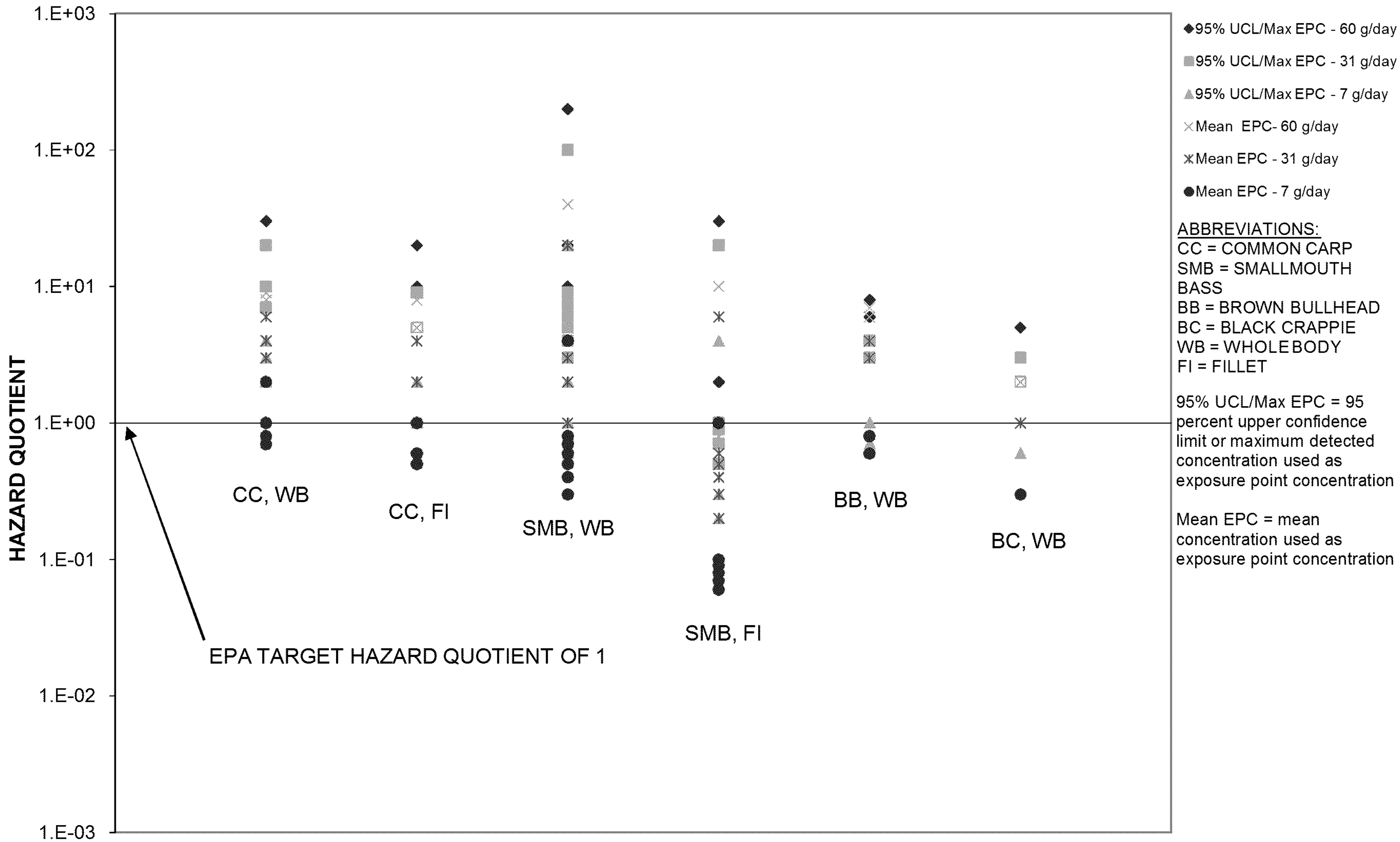

Figure 8
Non-Tribal Child Noncancer Hazard From Total Dioxin TEQ in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

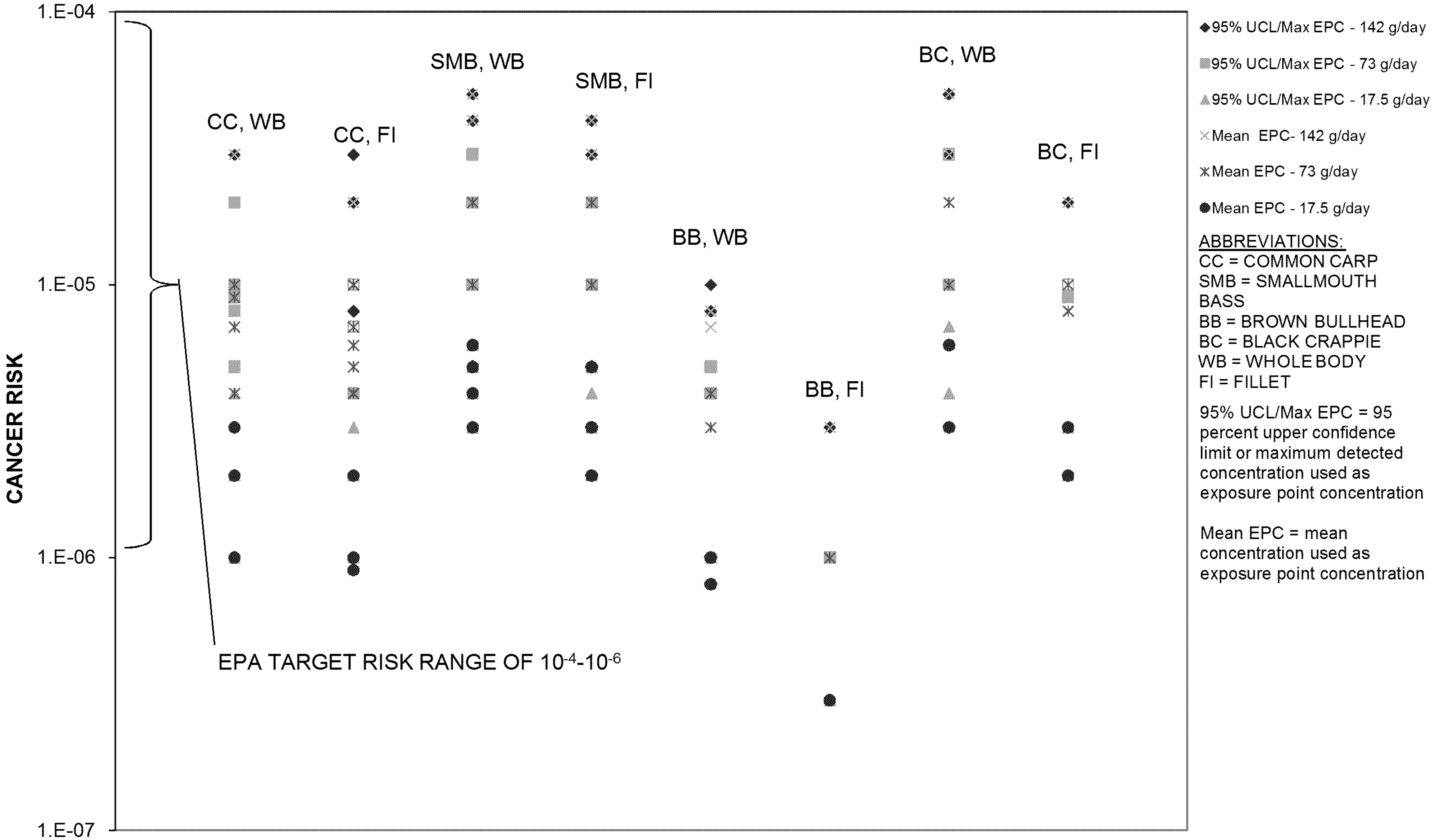

Figure 9
Non-Tribal Adult Cancer Risk From Arsenic in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

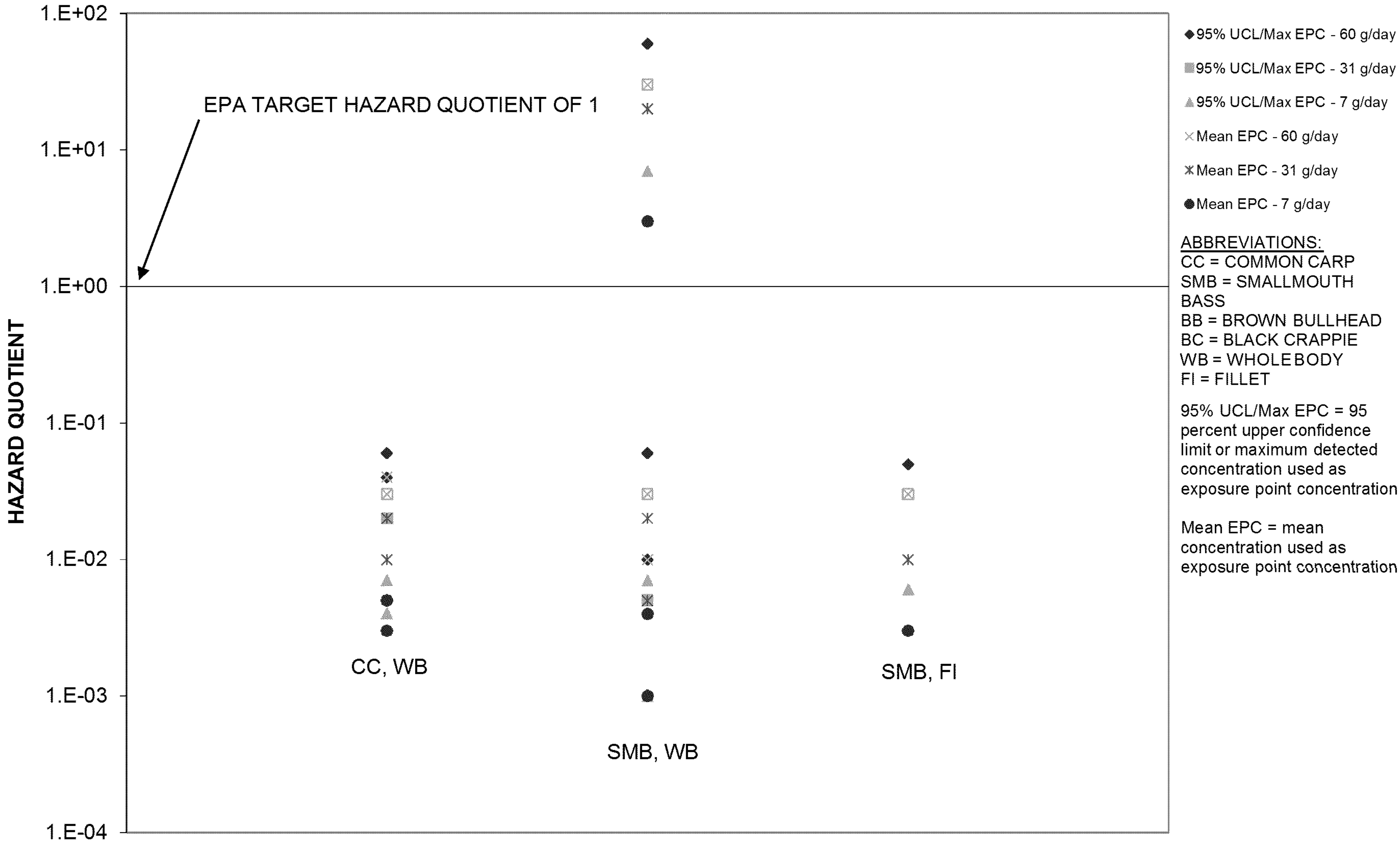

Figure 10
Non-Tribal Child Noncancer Hazard from Antimony in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

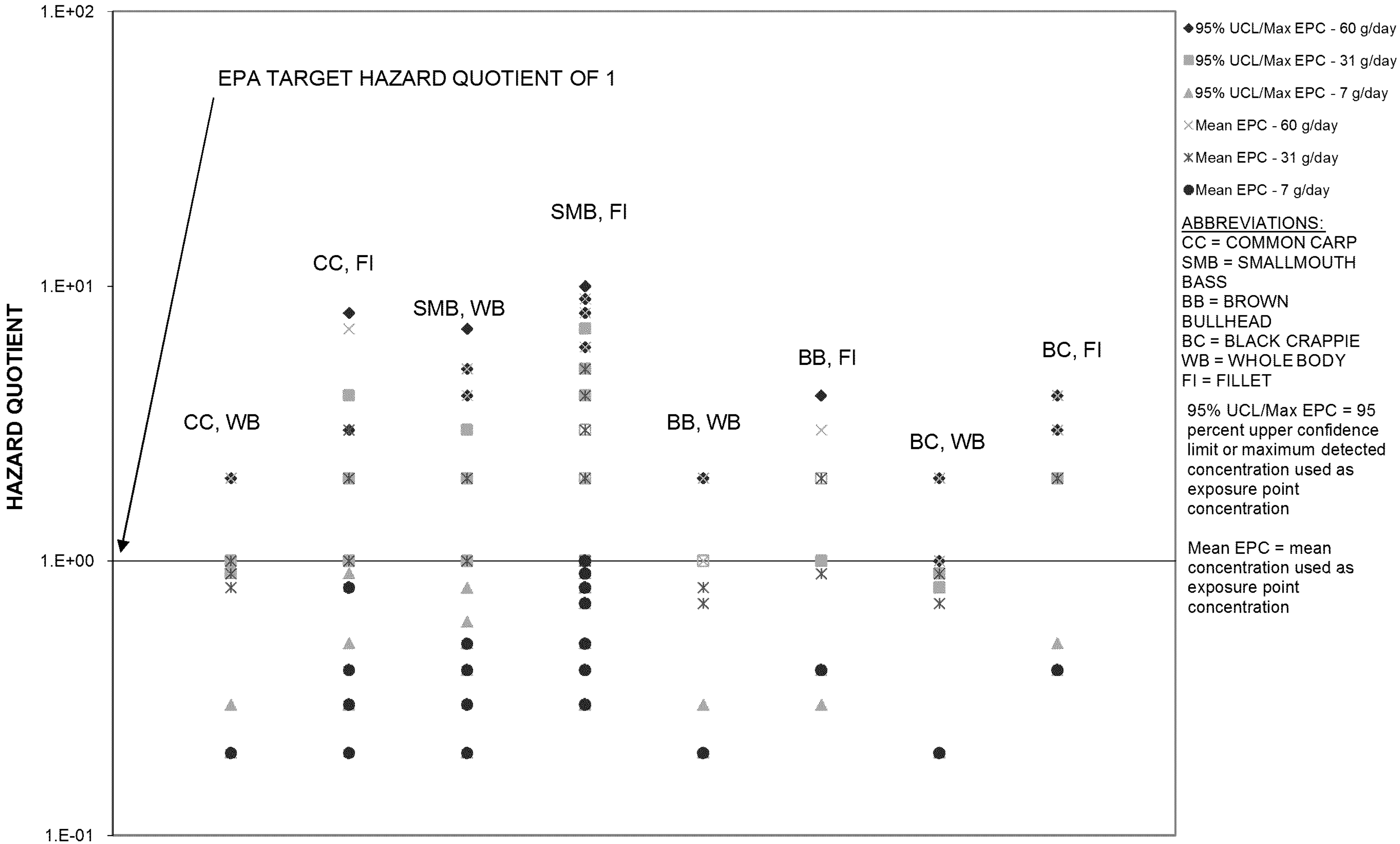

Figure 11
Non-Tribal Child Noncancer Hazard from Mercury in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

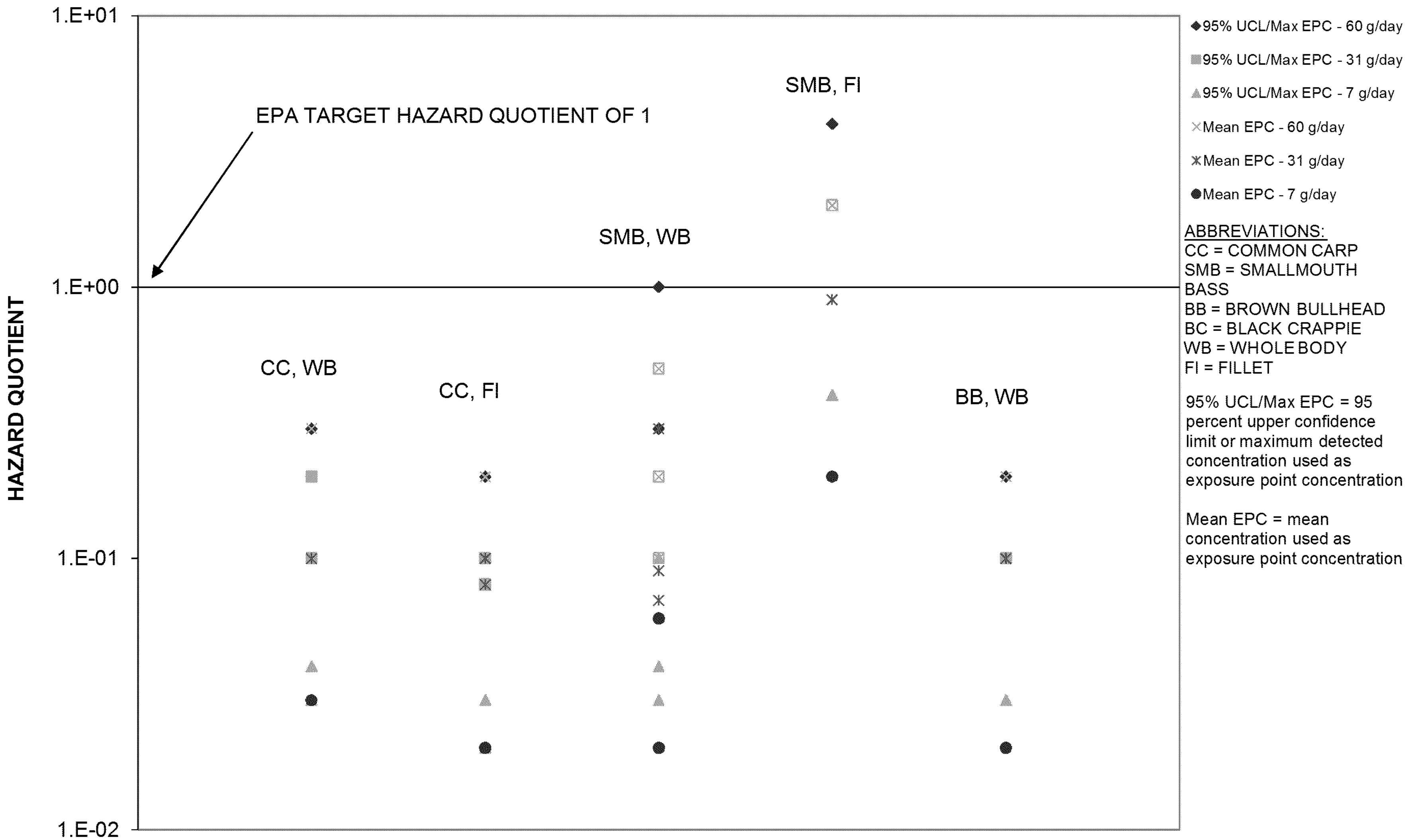

Figure 12
Non-Tribal Child Noncancer Hazard from Selenium in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

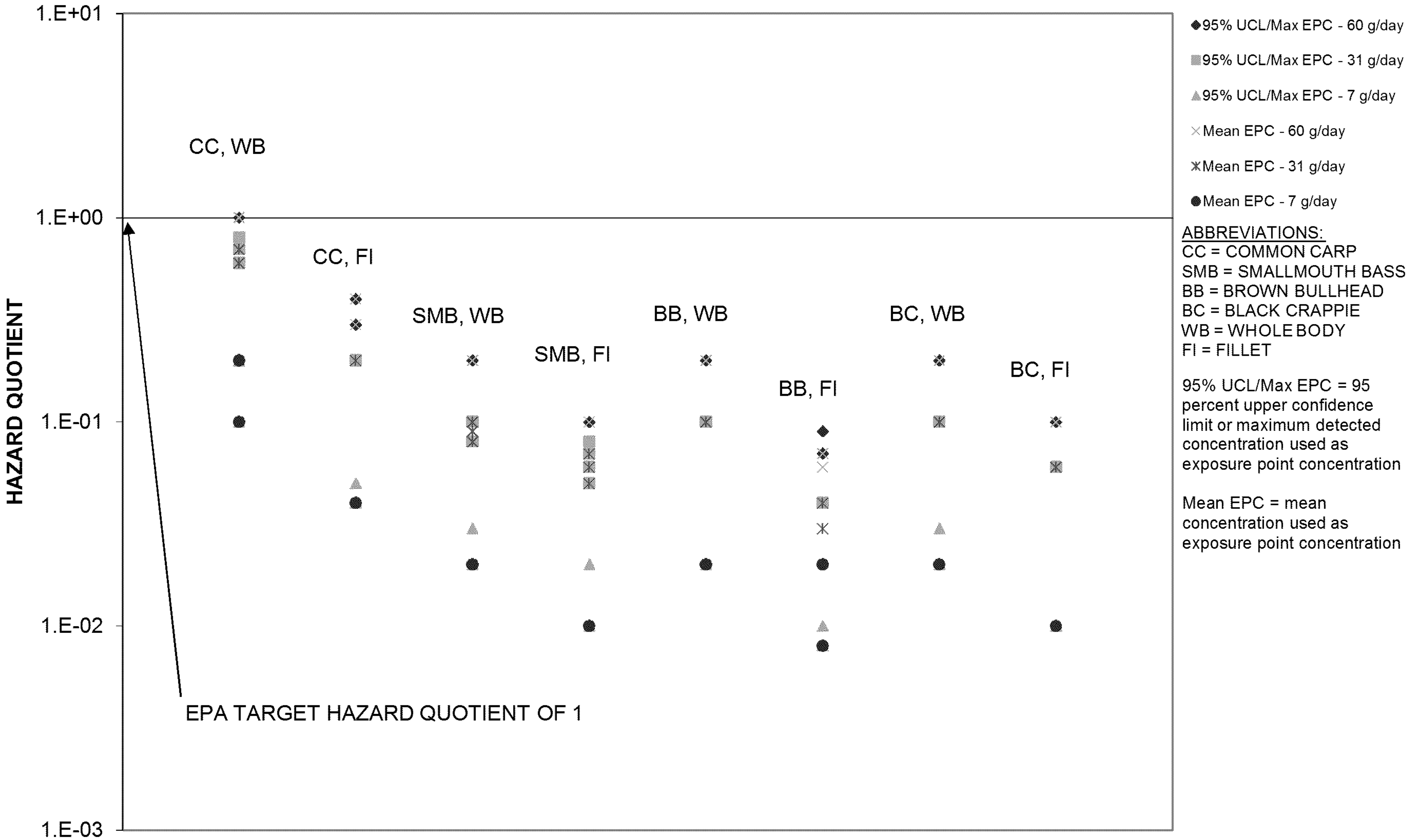

Figure 13
Non-Tribal Child Noncancer Hazard from Zinc in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

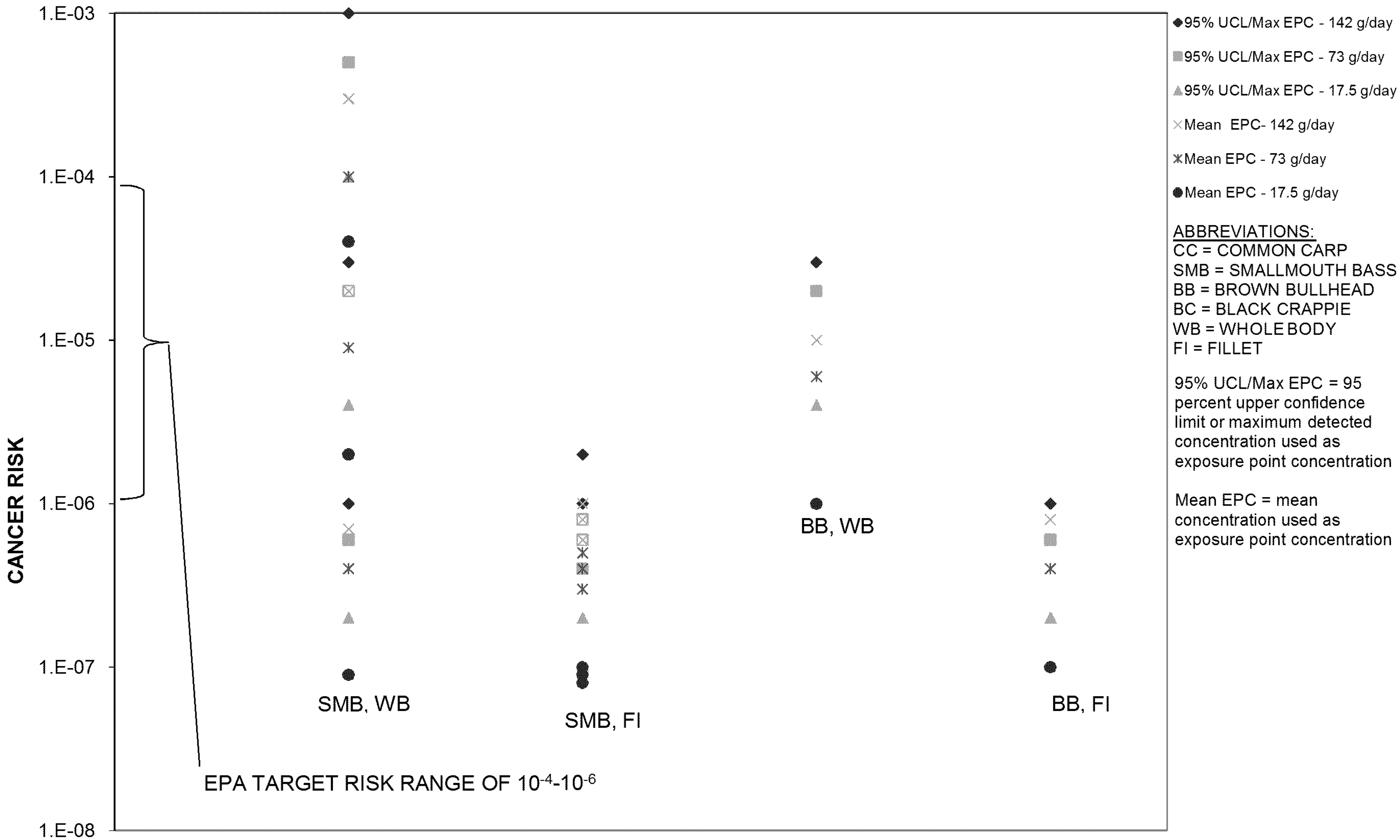

Figure 14
Non-Tribal Adult Cancer Risk From Bis(2-ethylhexyl) phthalate in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

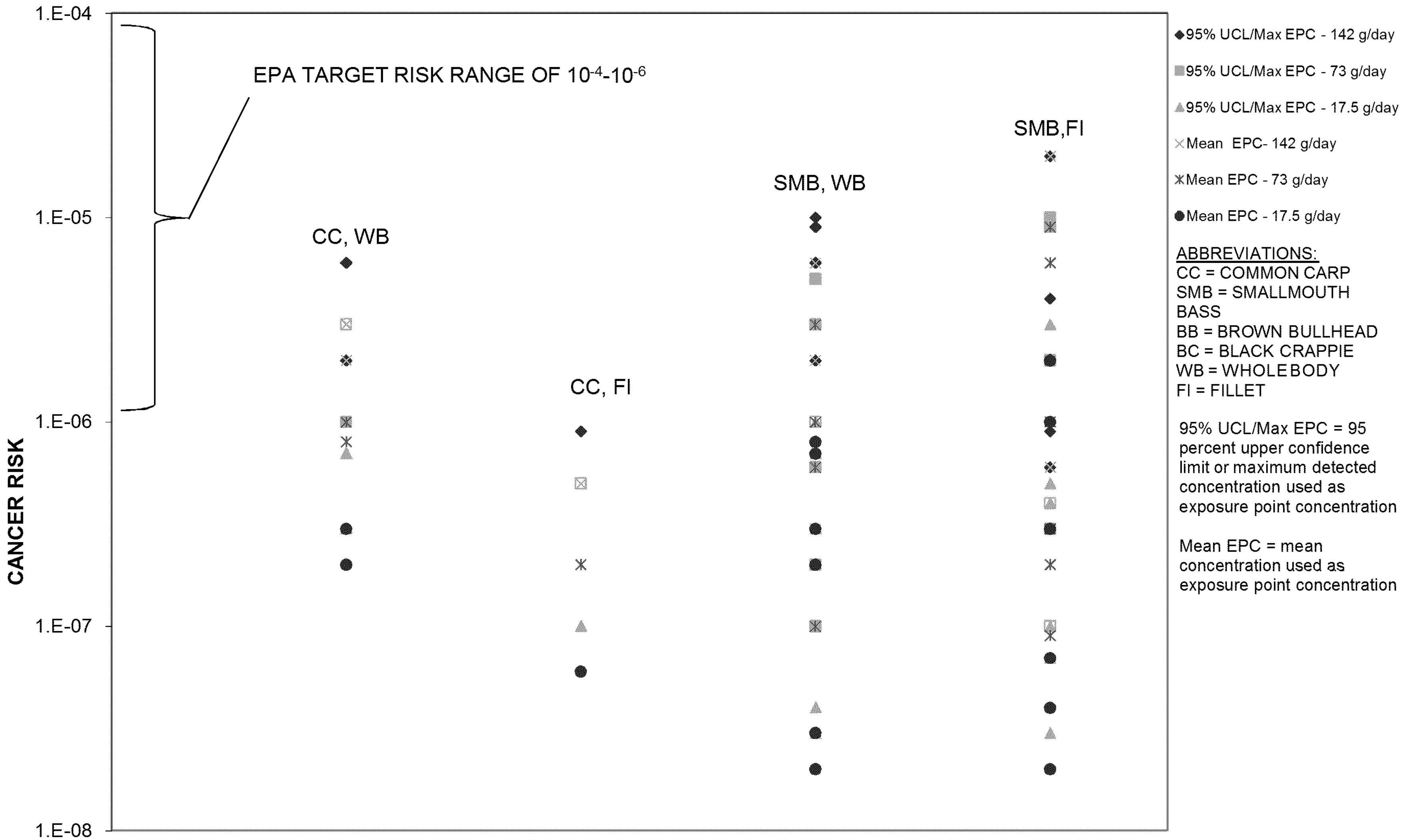

Figure 15
Non-Tribal Adult Cancer Risk From Total Carcinogenic PAHs in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

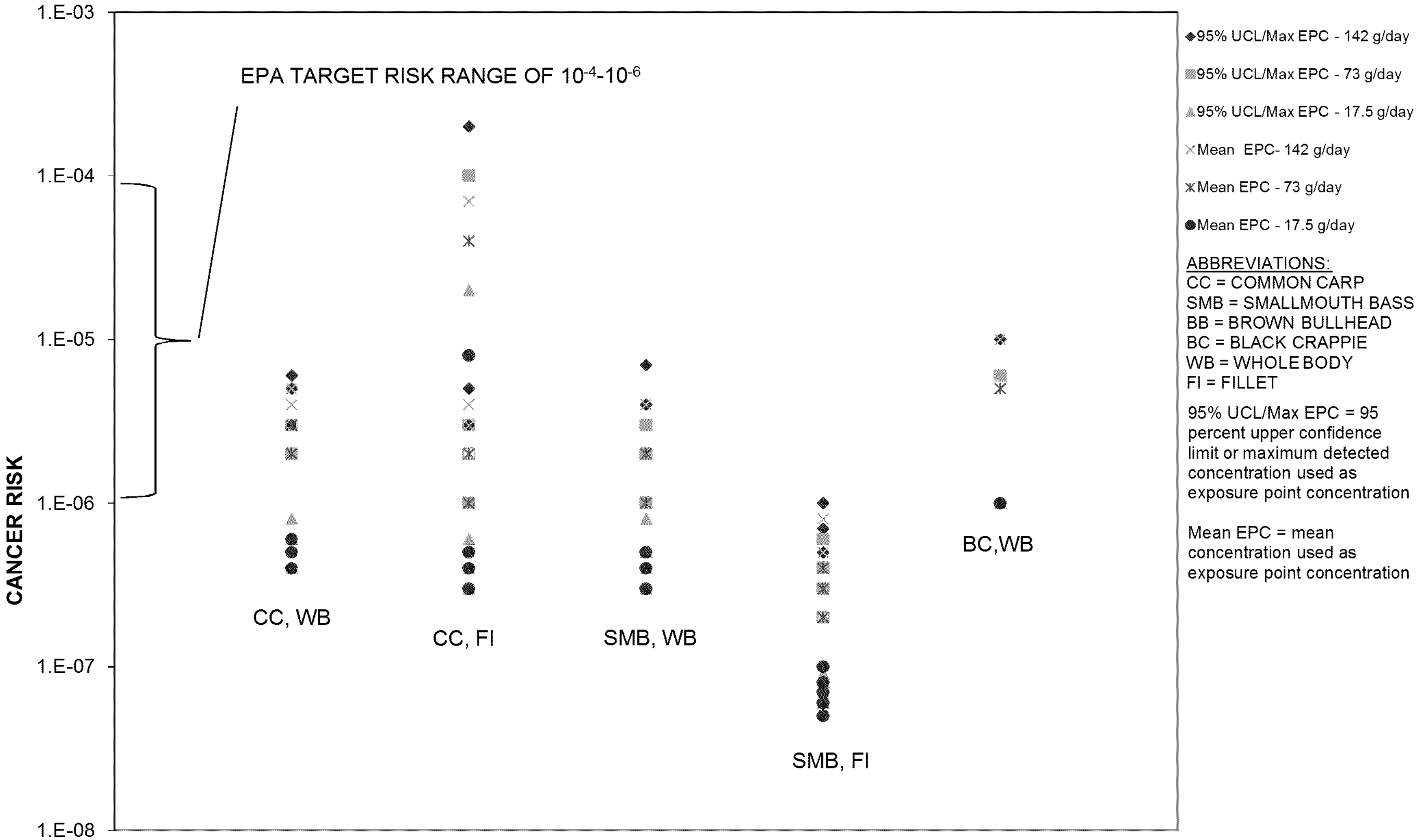

Figure 16
Non-Tribal Adult Cancer Risk From Hexachlorobenzene in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

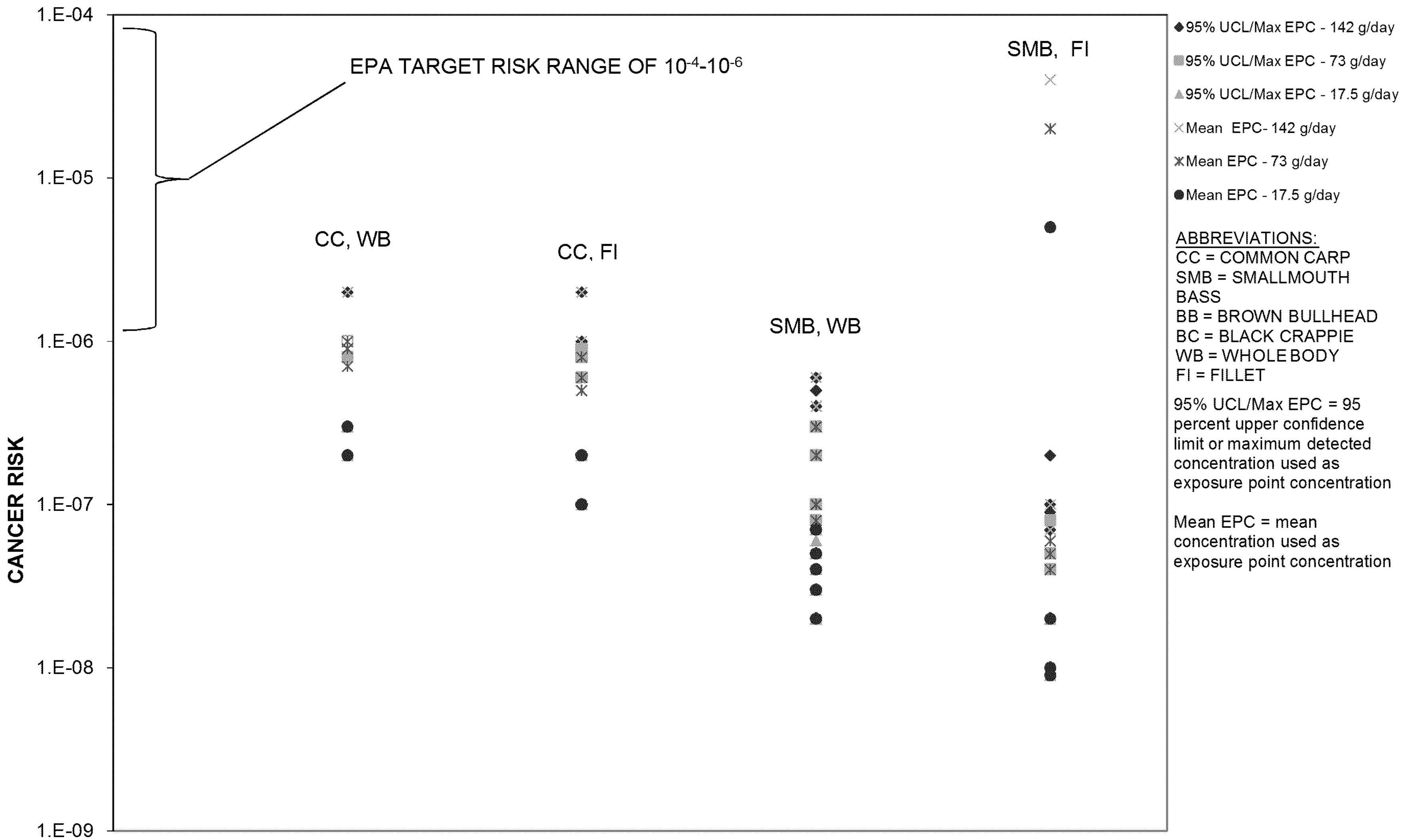

Figure 17
Non-Tribal Adult Cancer Risk From Aldrin in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

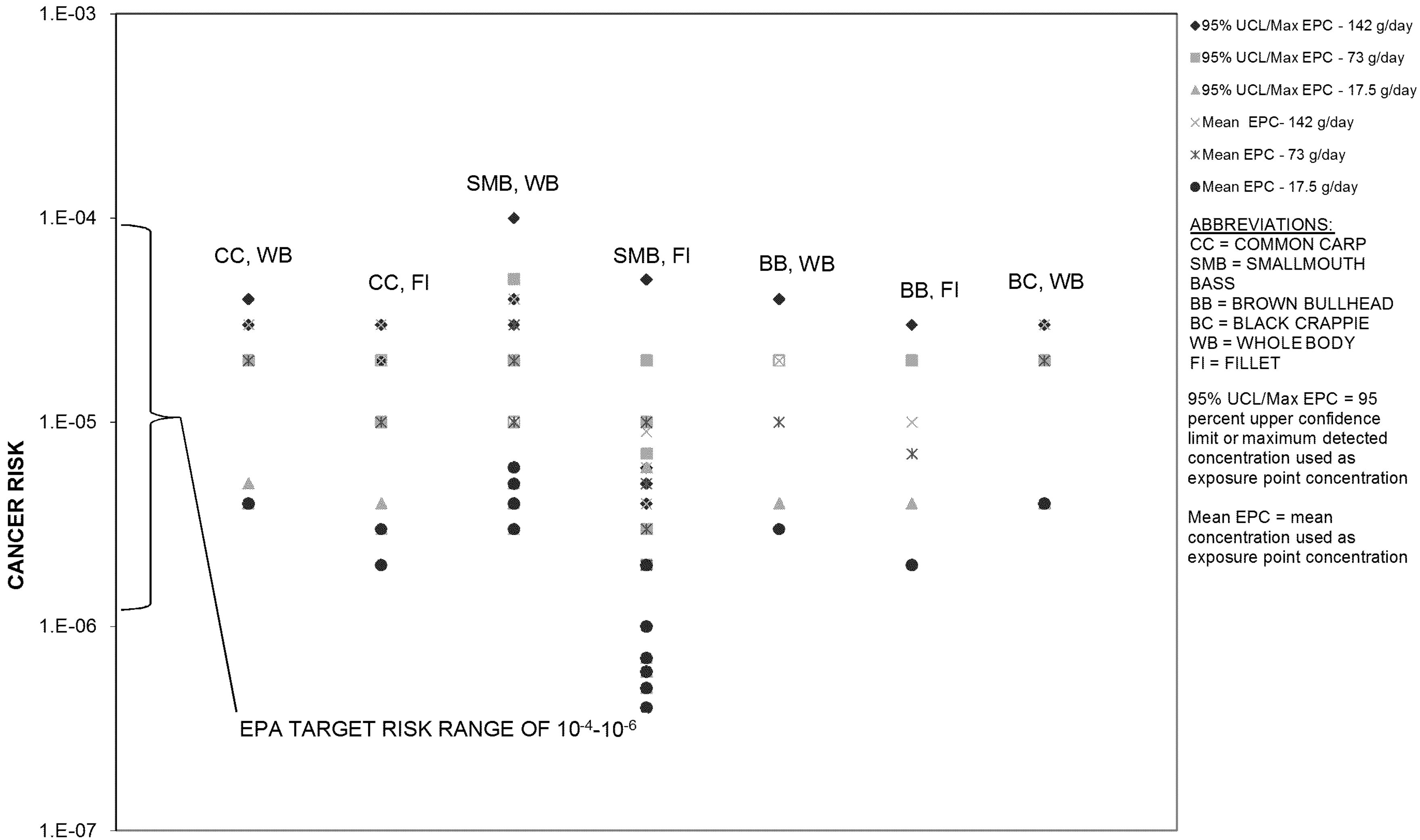

Figure 18
Non-Tribal Adult Cancer Risk From Dieldrin in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

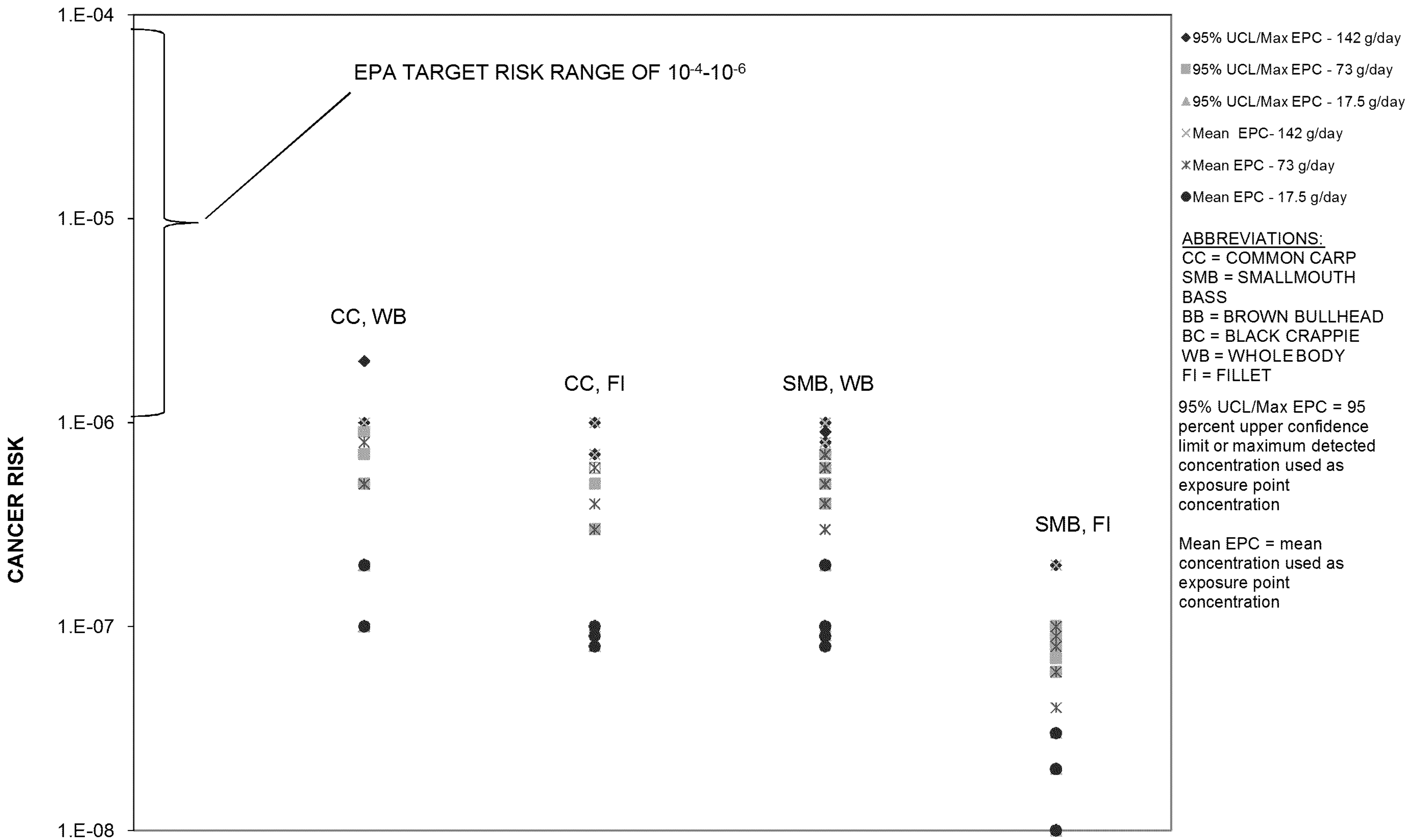

Figure 19
Non-Tribal Adult Cancer Risk From Heptachlor Epoxide in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

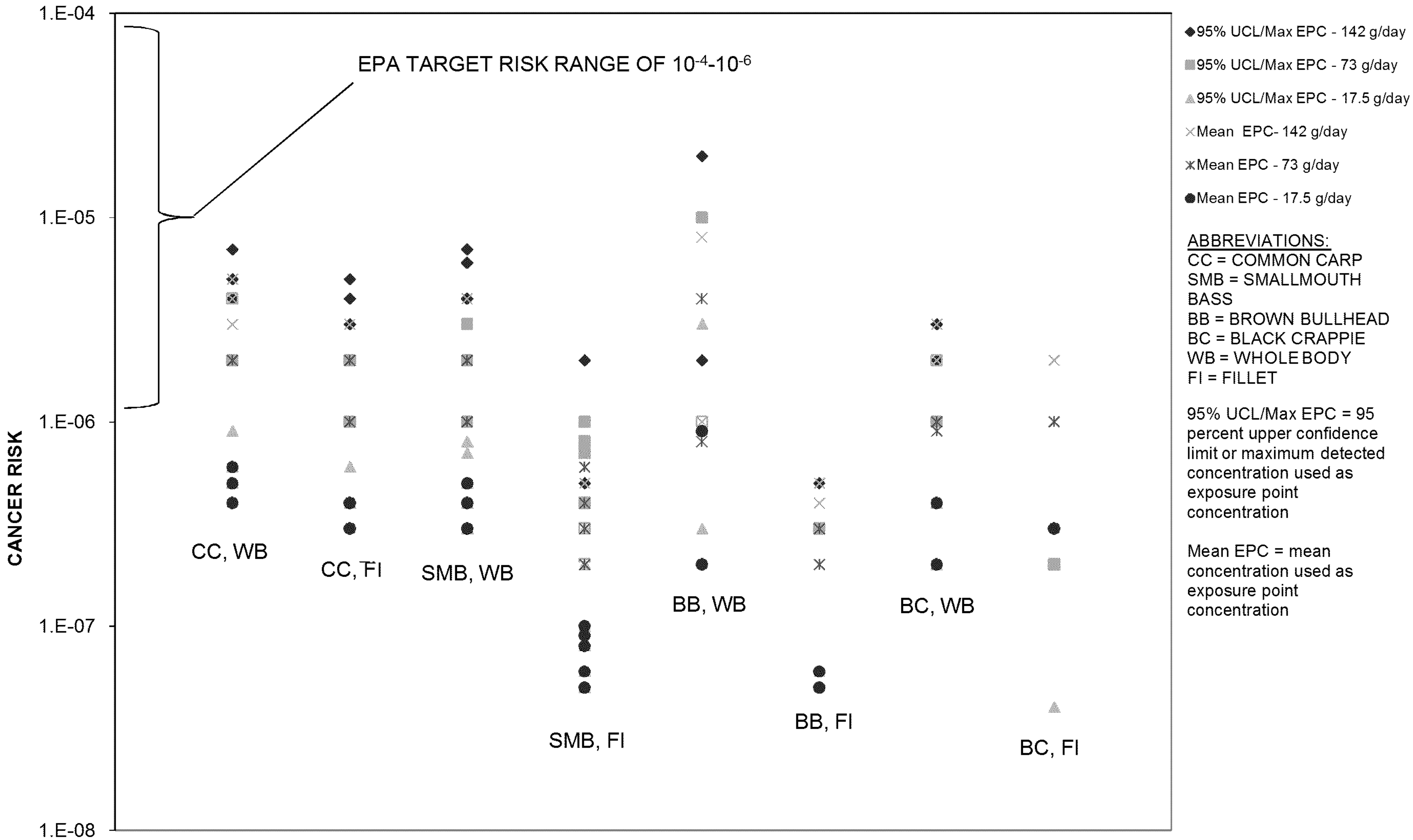

Figure 20
Non-Tribal Adult Cancer Risk From Total Chlordanes in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

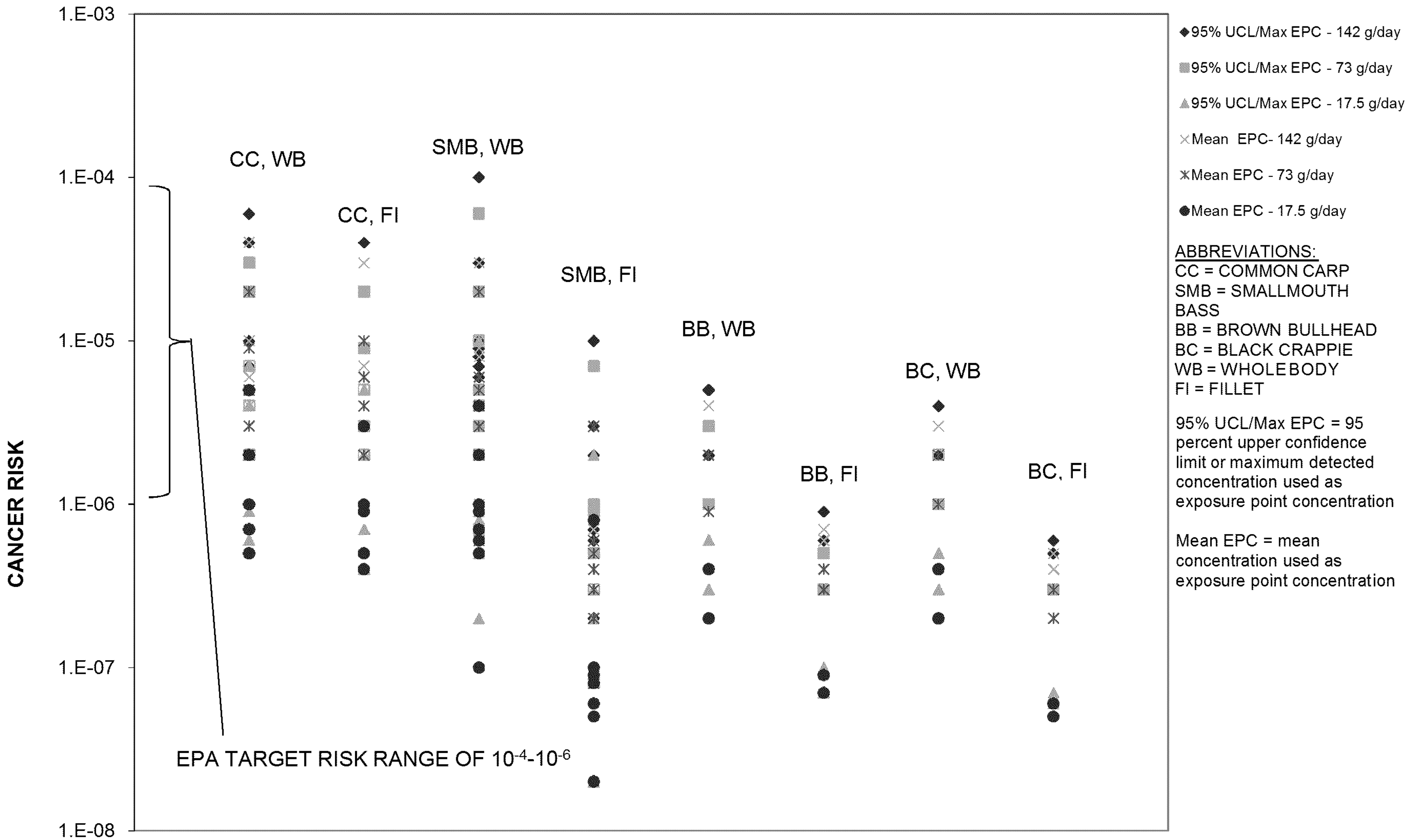

Figure 21
Non-Tribal Adult Cancer Risk From Total DDD in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

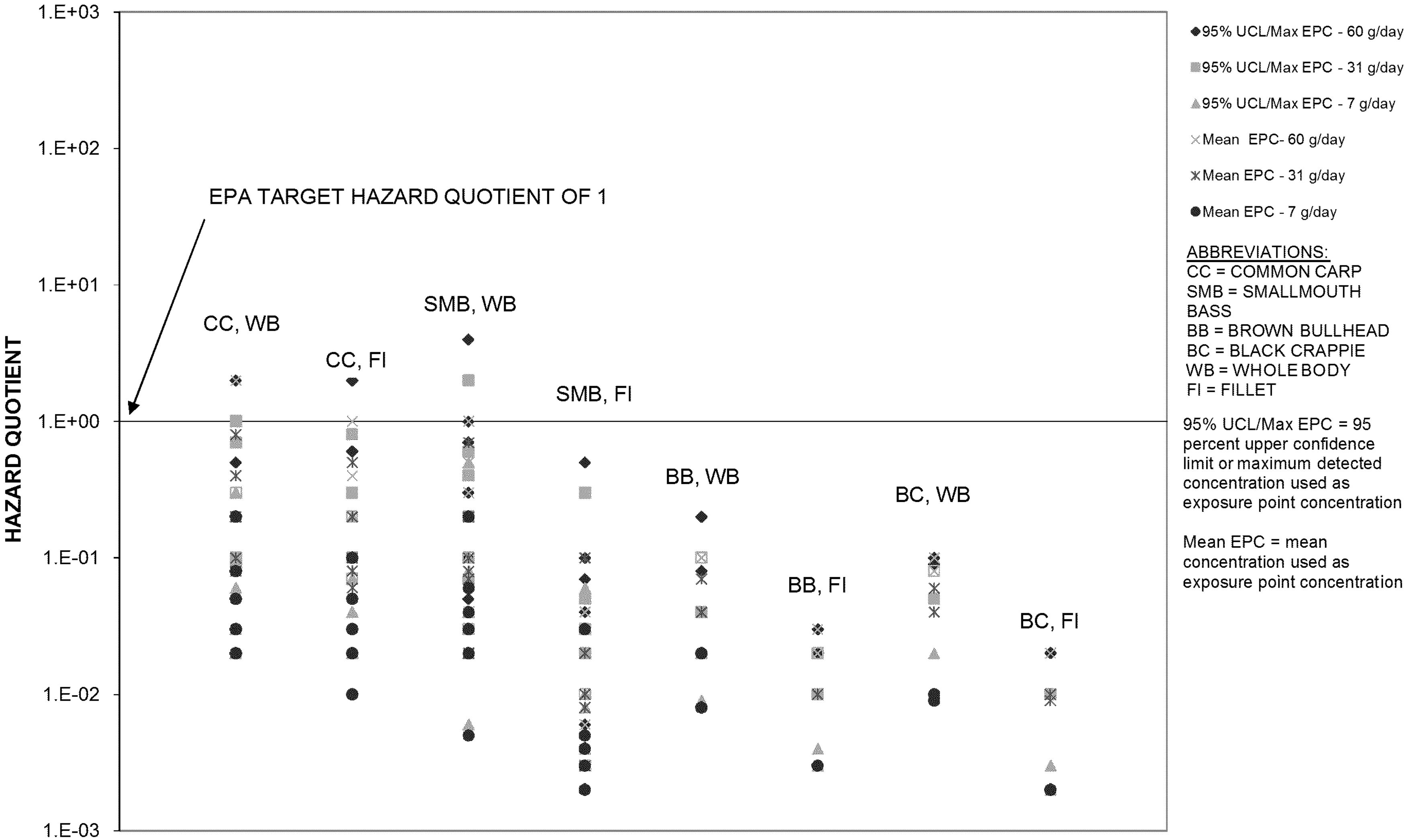

Figure 22
Non-Tribal Child Noncancer Hazard From Total DDD in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

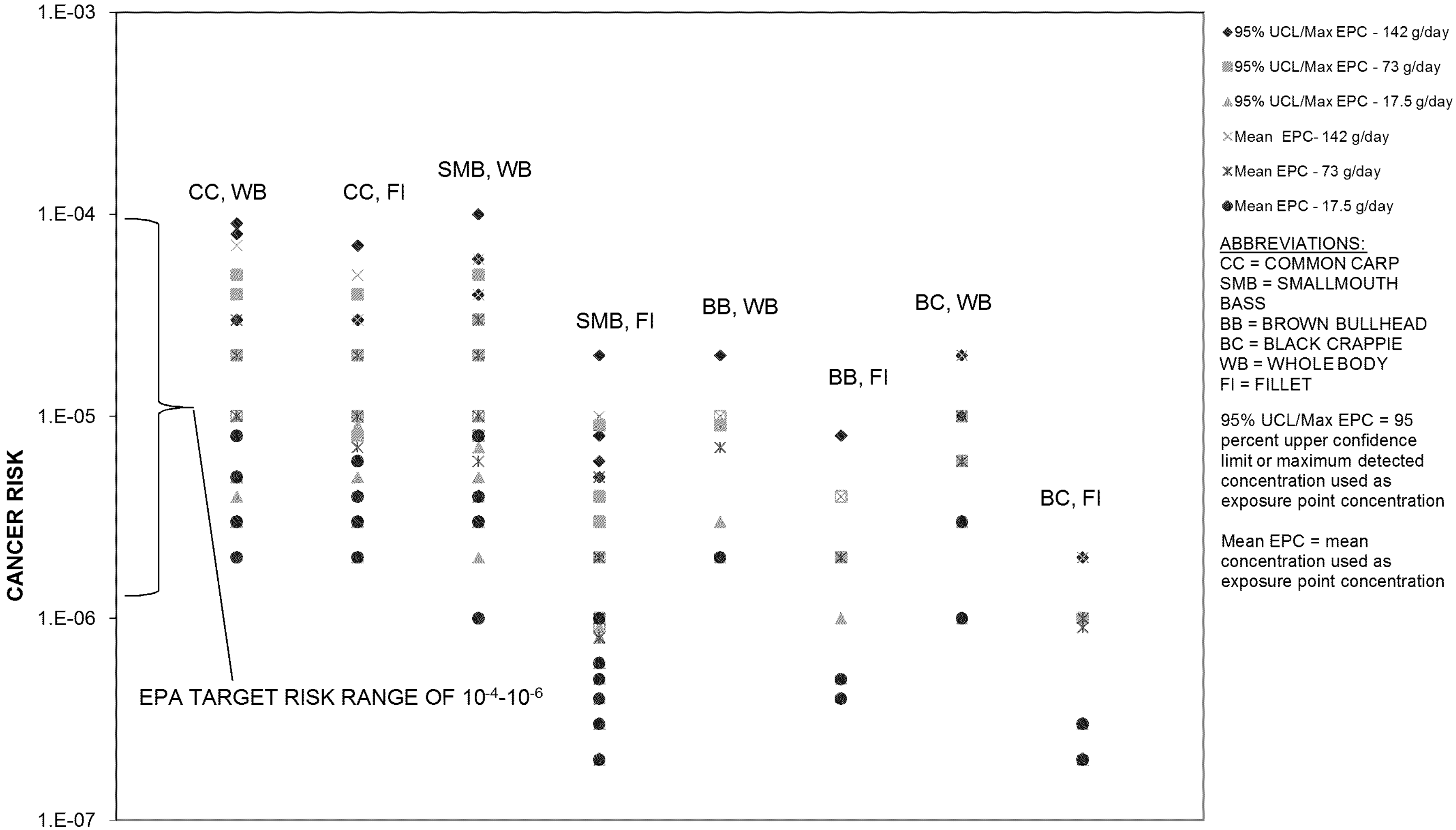

Figure 23
Non-Tribal Adult Cancer Risk From Total DDE in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

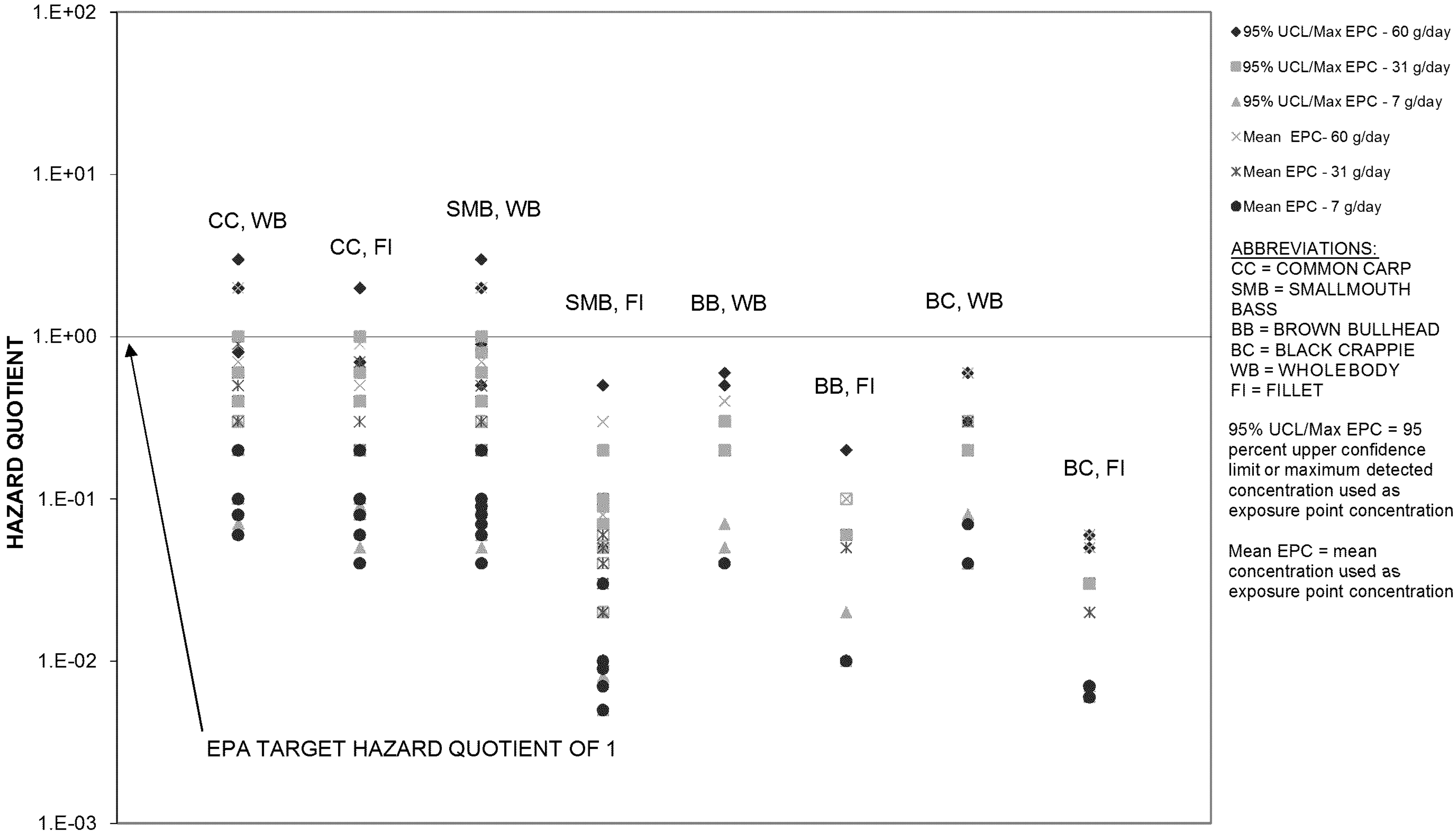

Figure 24
Non-Tribal Child Noncancer Hazard From Total DDE in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

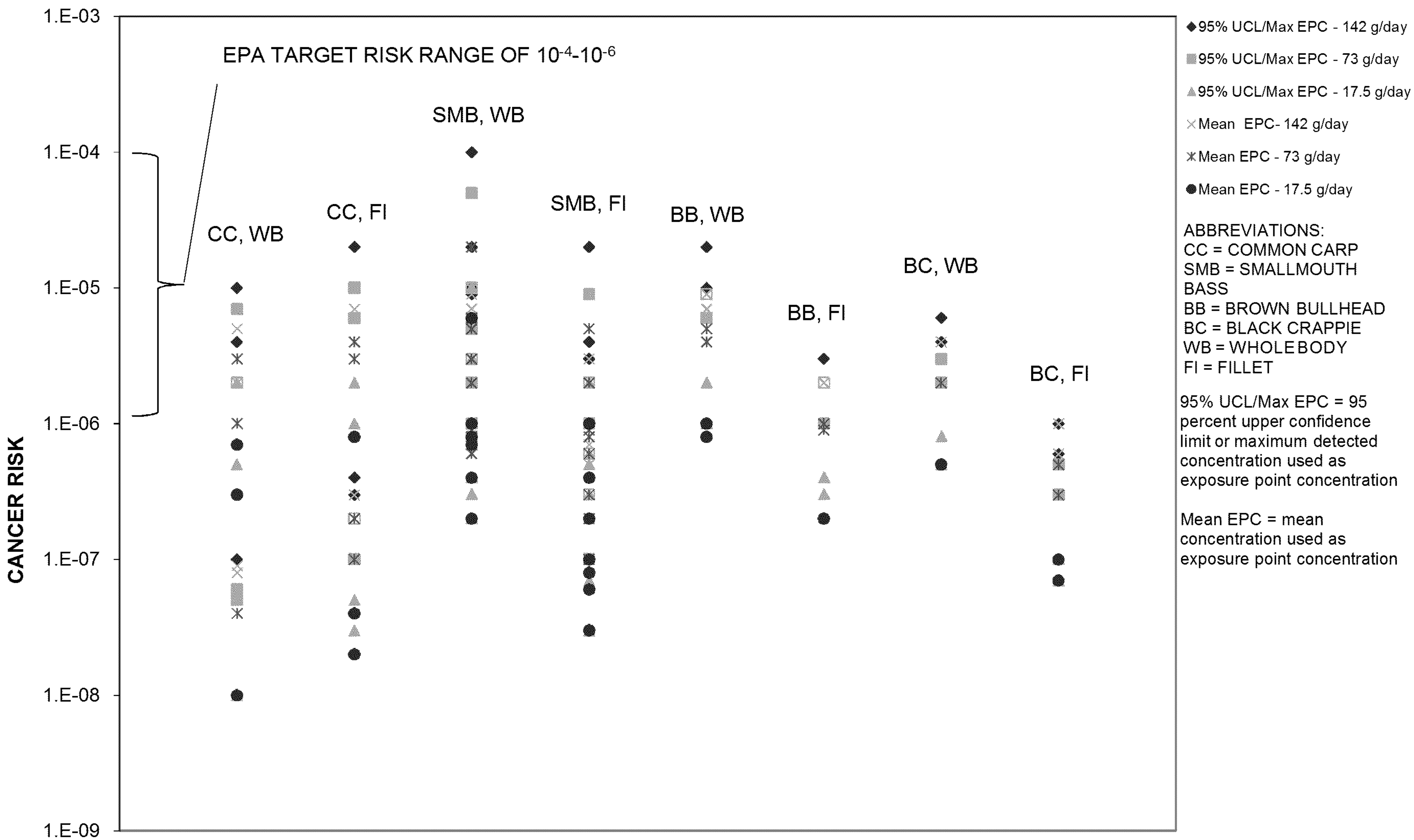

Figure 25
Non-Tribal Adult Cancer Risk From Total DDT in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

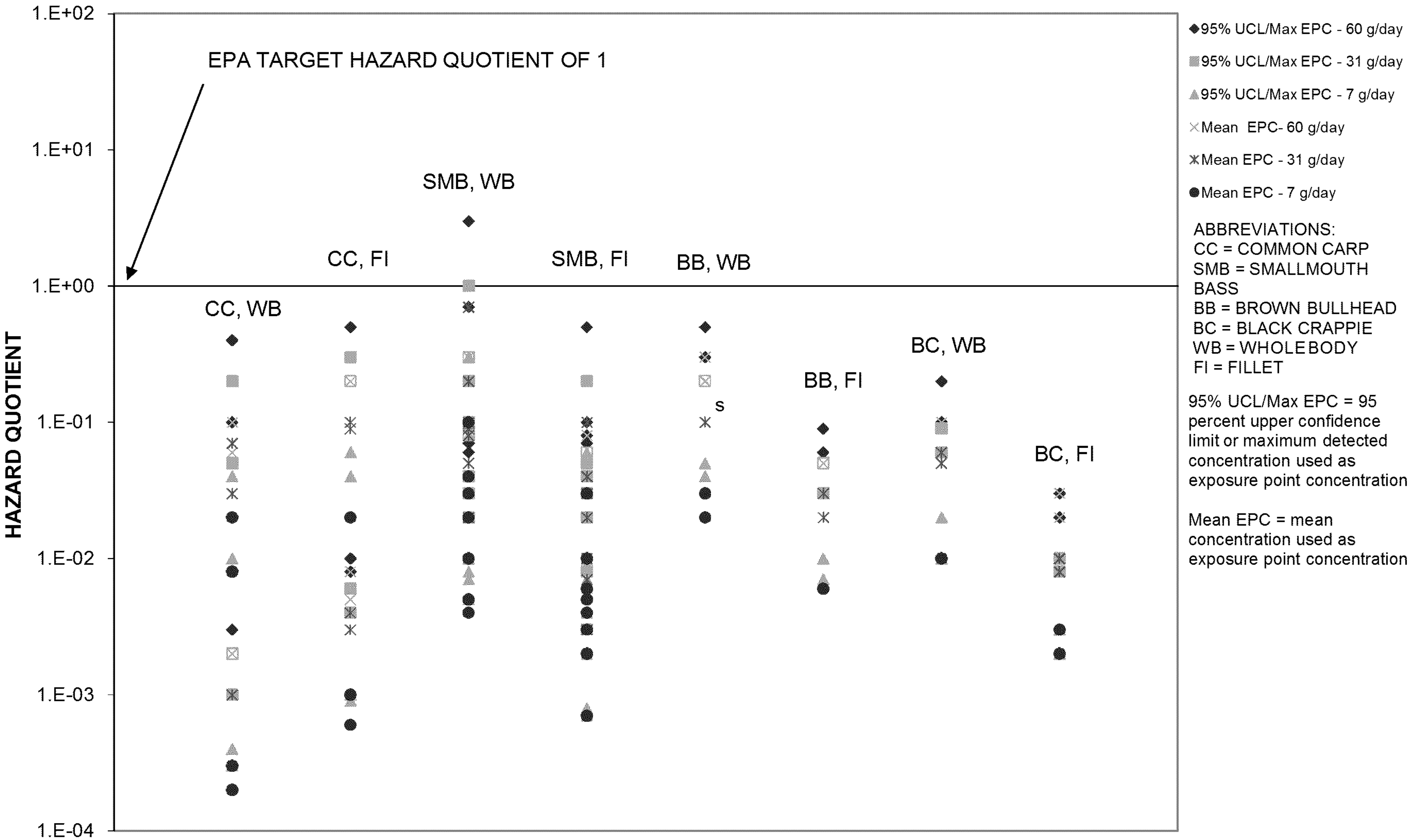

Figure 26
Non-Tribal Child Noncancer Hazard From Total DDT in Fish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

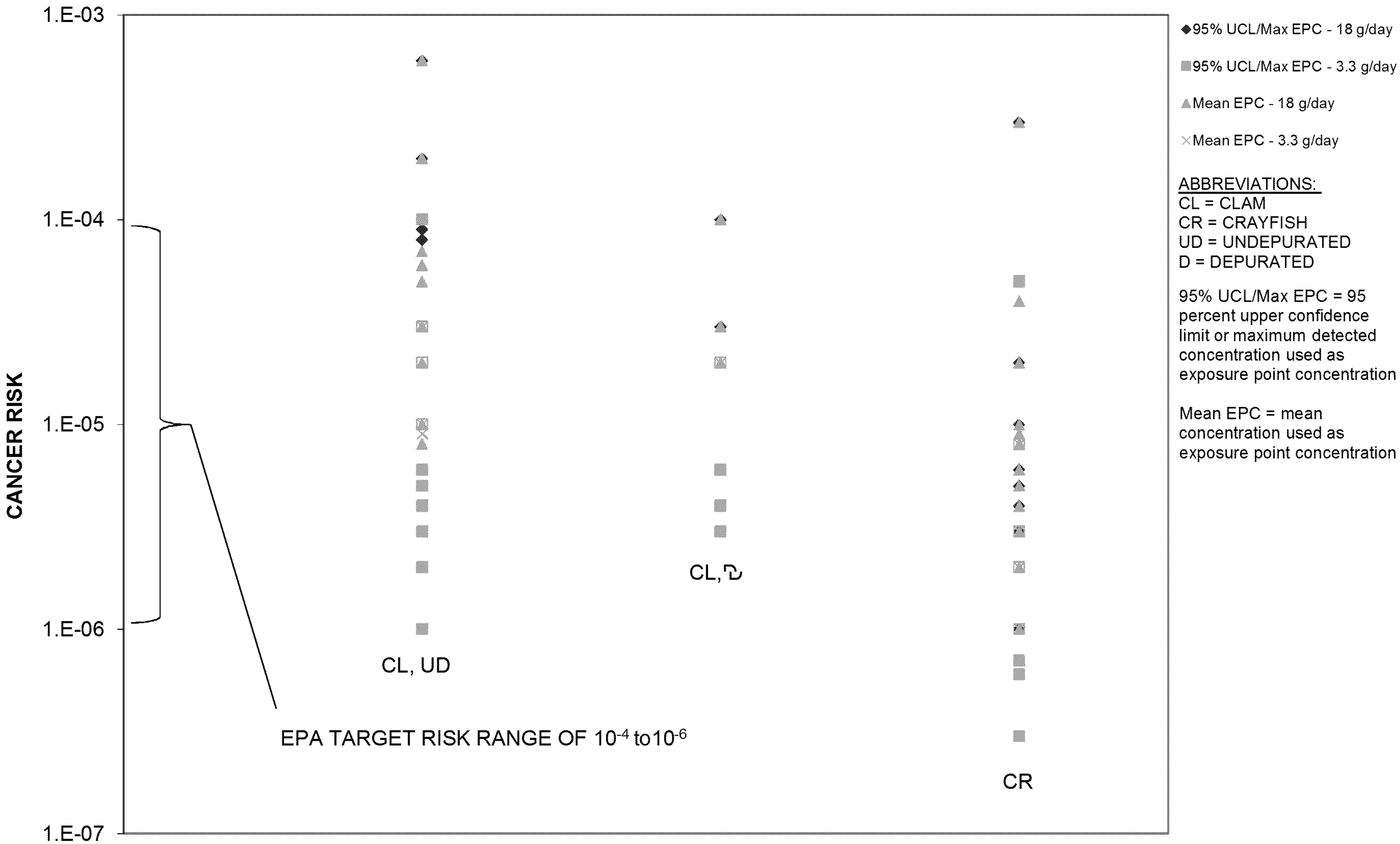

Figure 27
Non-Tribal Adult Cancer Risk From Total PCBs in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

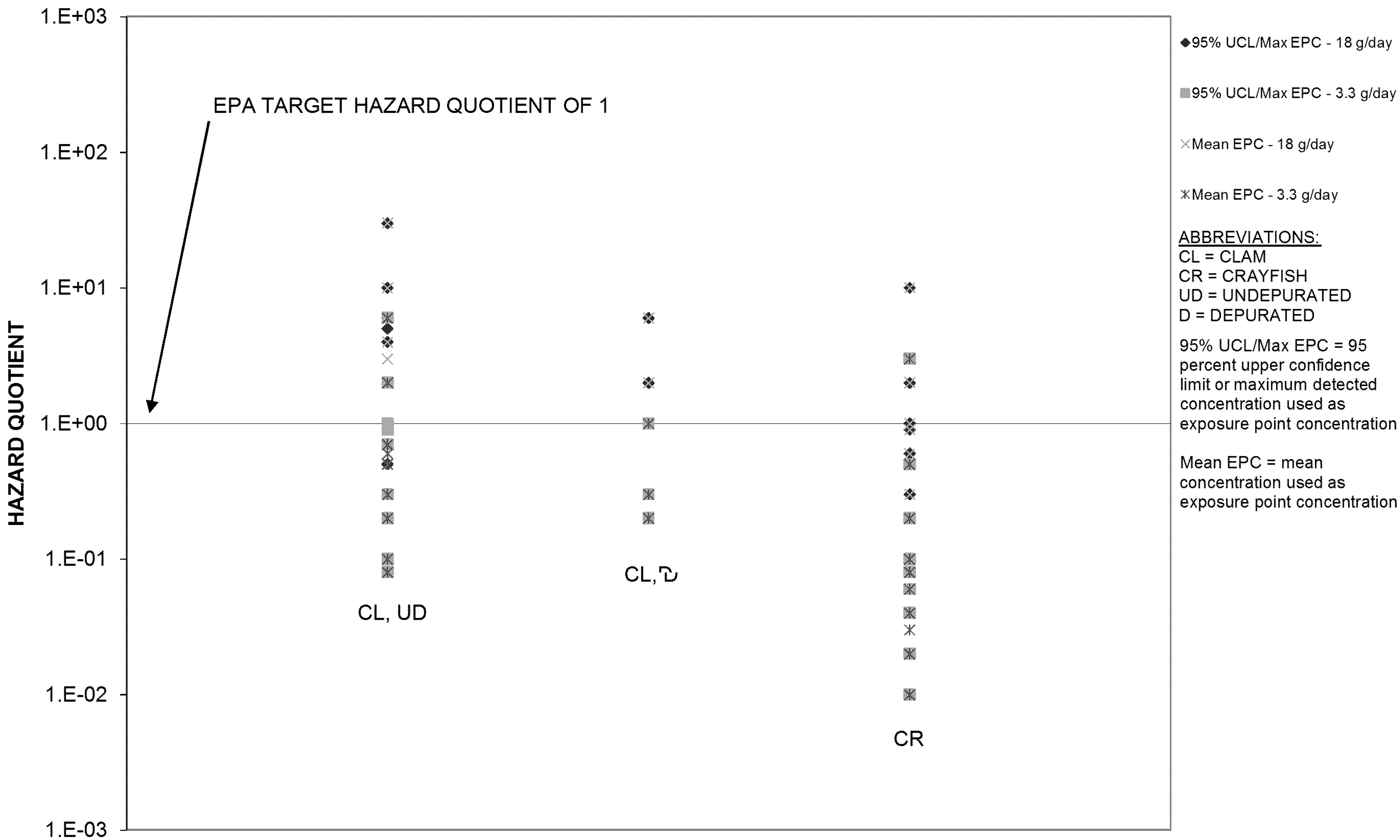

Figure 28
Non-Tribal Adult Noncancer Hazard From Total PCBs in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

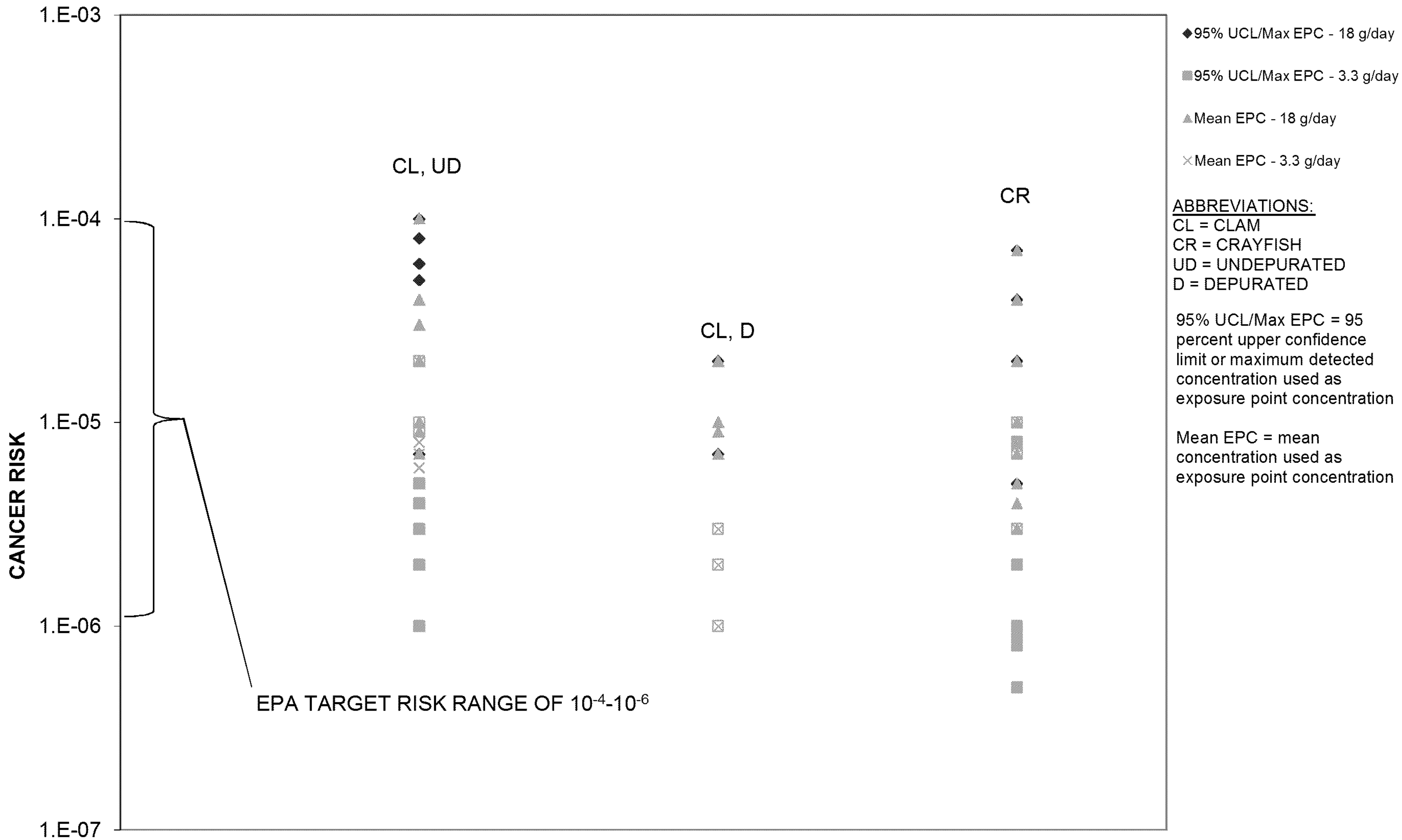

Figure 29
Non-Tribal Adult Cancer Risk From Total PCB TEQ in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

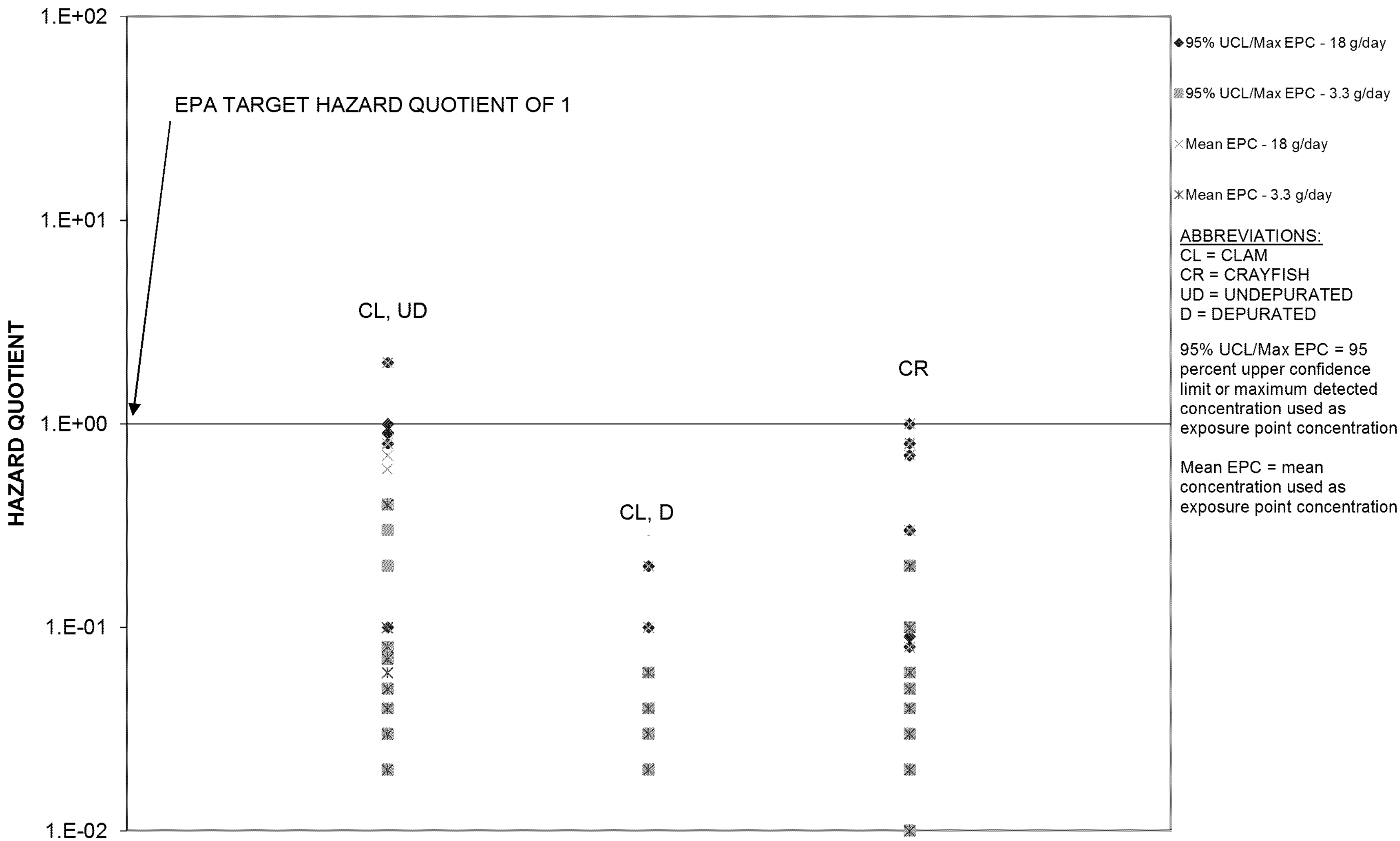

Figure 30
Non-Tribal Adult Noncancer Hazard From Total PCB TEQ in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

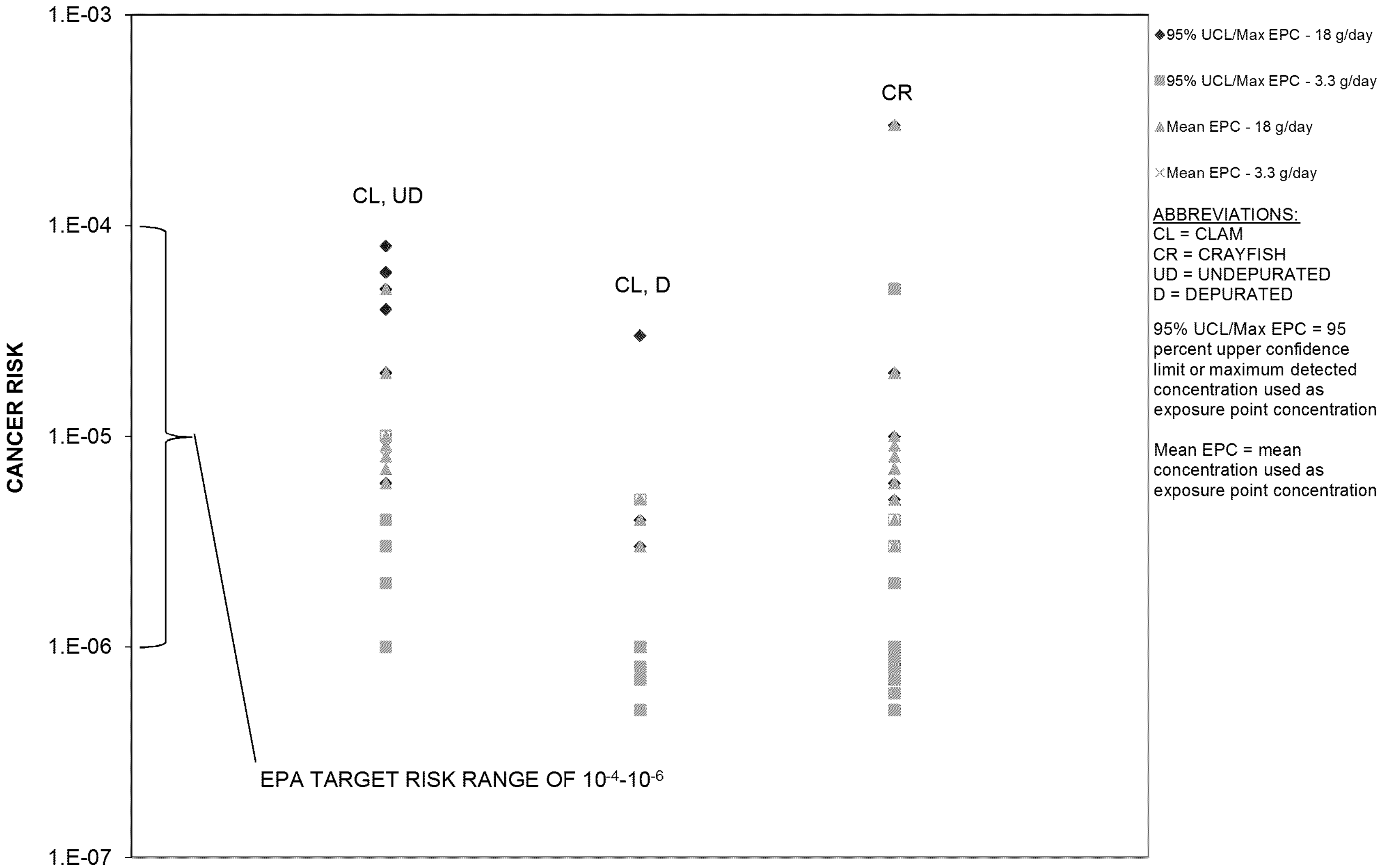

Figure 31
Non-Tribal Adult Cancer Risk From Total Dioxin TEQ in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

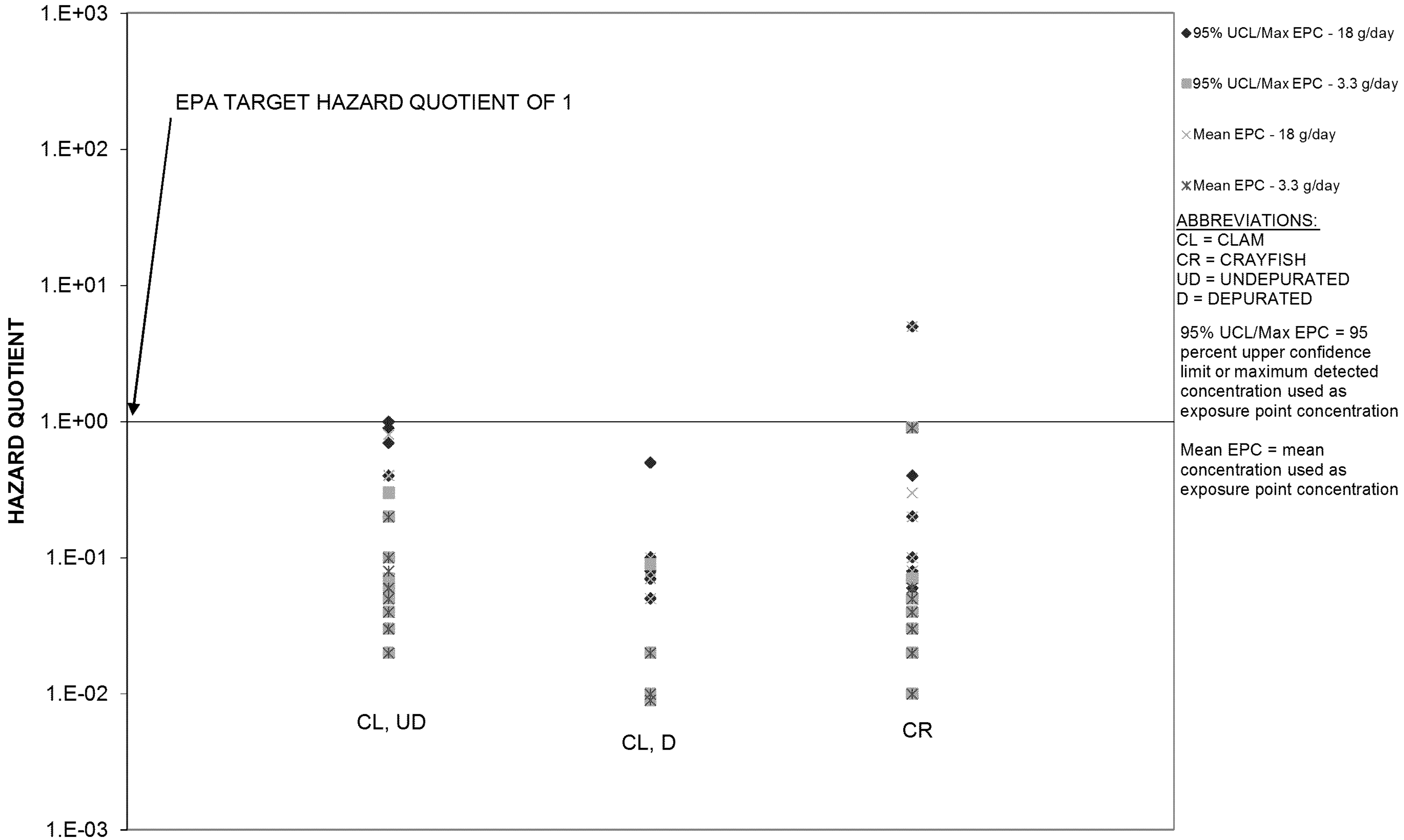

Figure 32
Non-Tribal Adult Noncancer Hazard From Total Dioxin TEQ in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

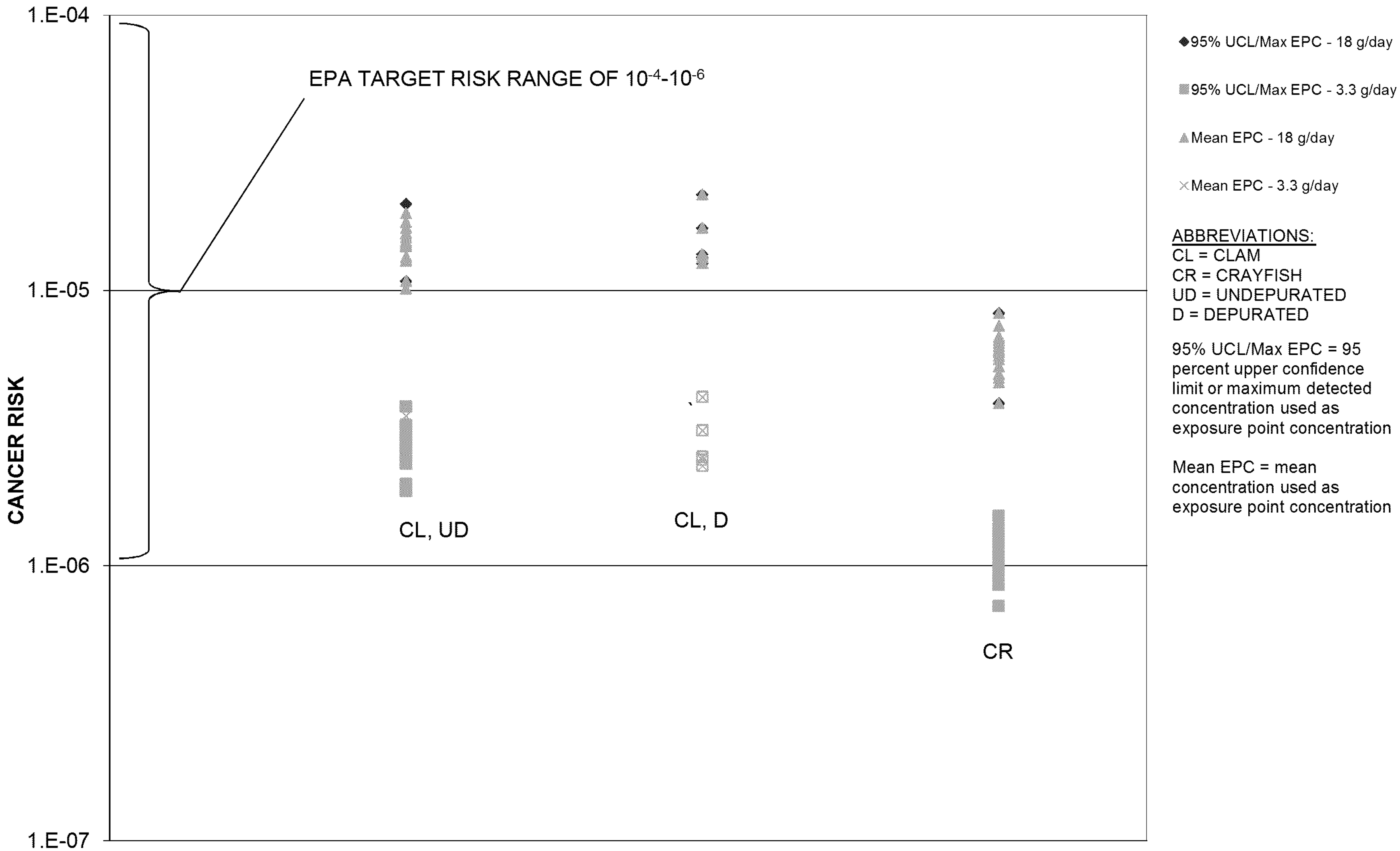

Figure 33
Non-Tribal Adult Cancer Risk From Arsenic in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

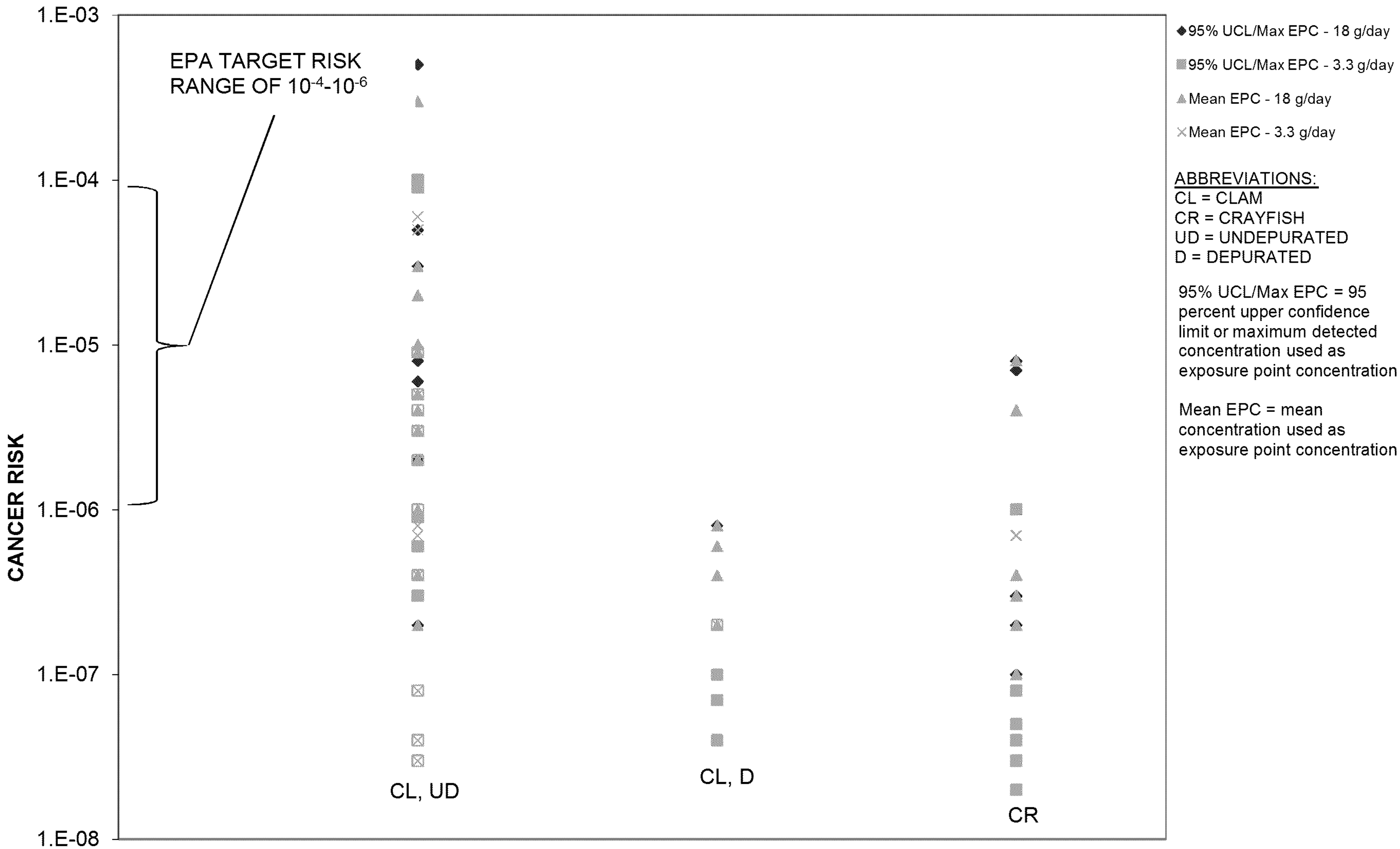

Figure 34
Non-Tribal Adult Cancer Risk From Total Carcinogenic PAHs in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

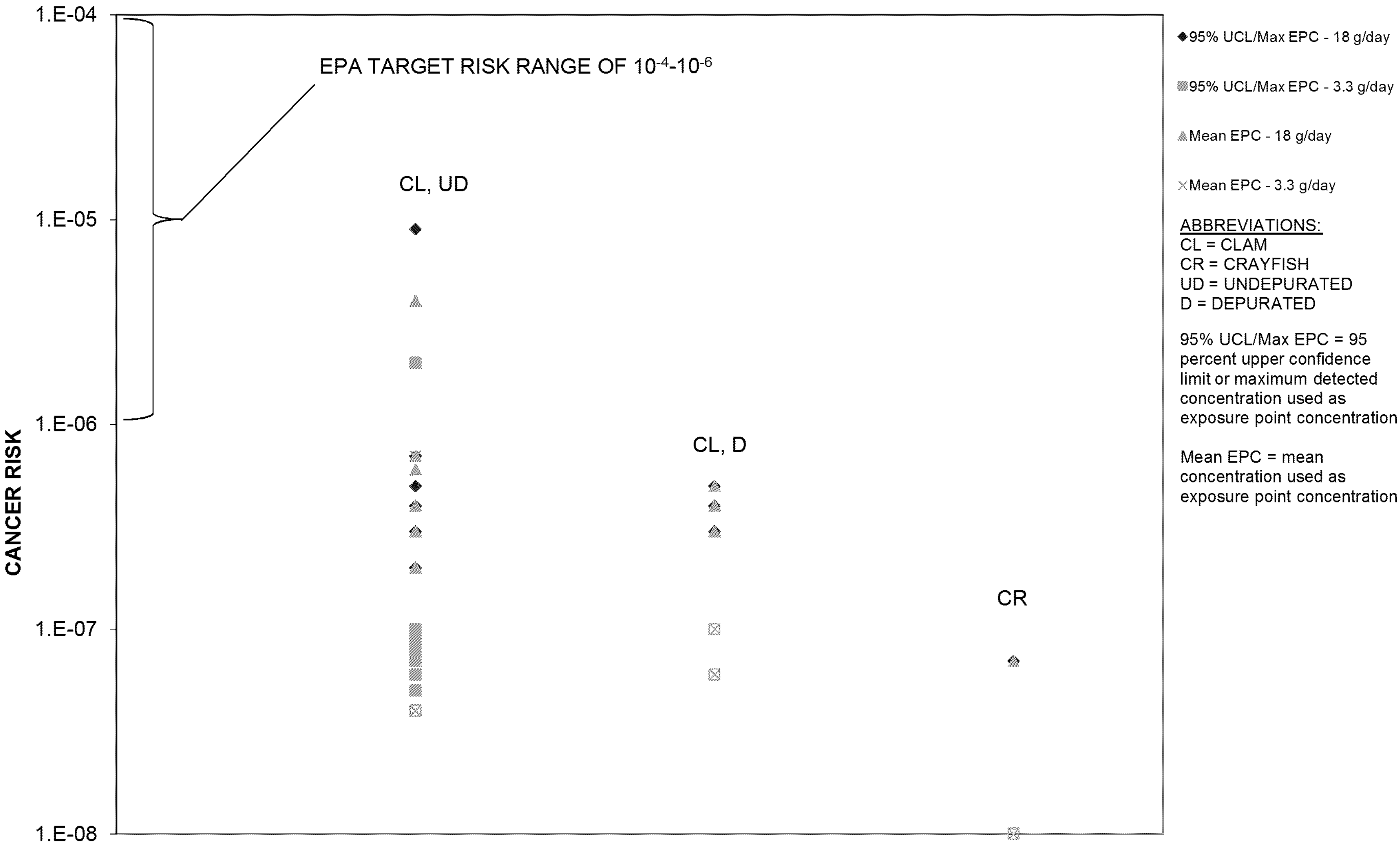

Figure 35
Non-Tribal Adult Cancer Risk From Aldrin in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

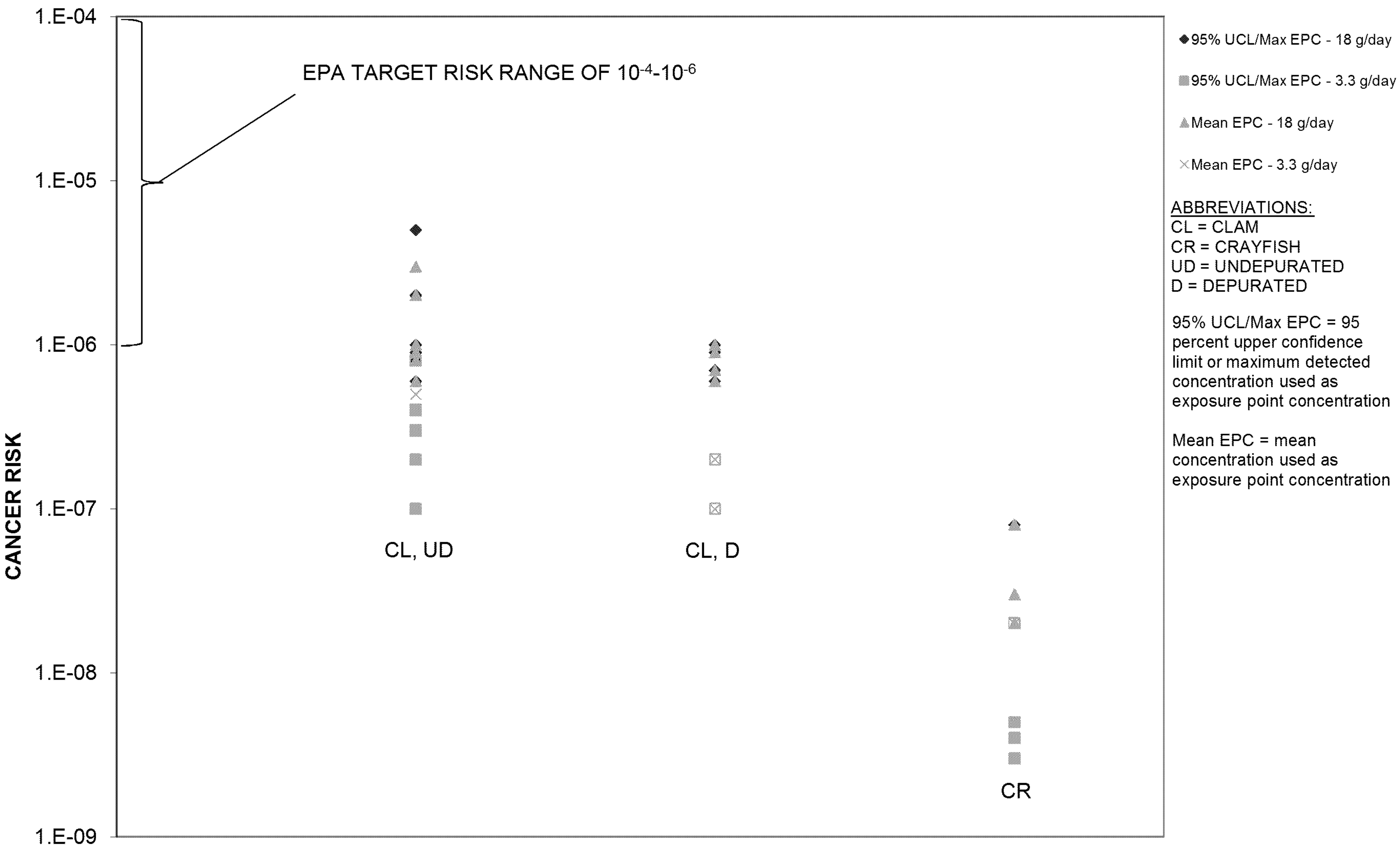

Figure 36
Non-Tribal Adult Cancer Risk From Dieldrin in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

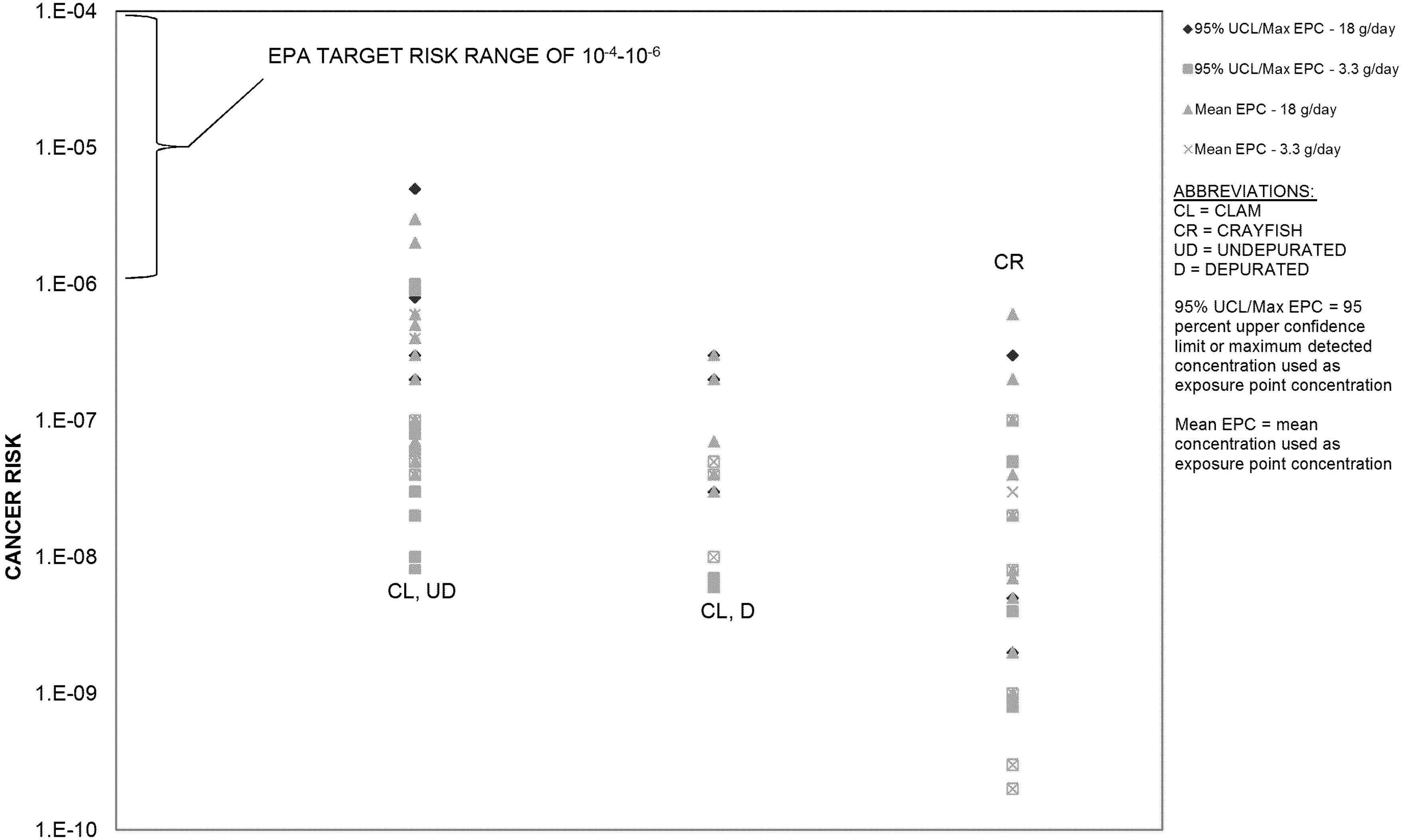

Figure 37
Non-Tribal Adult Cancer Risk From Total DDD in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

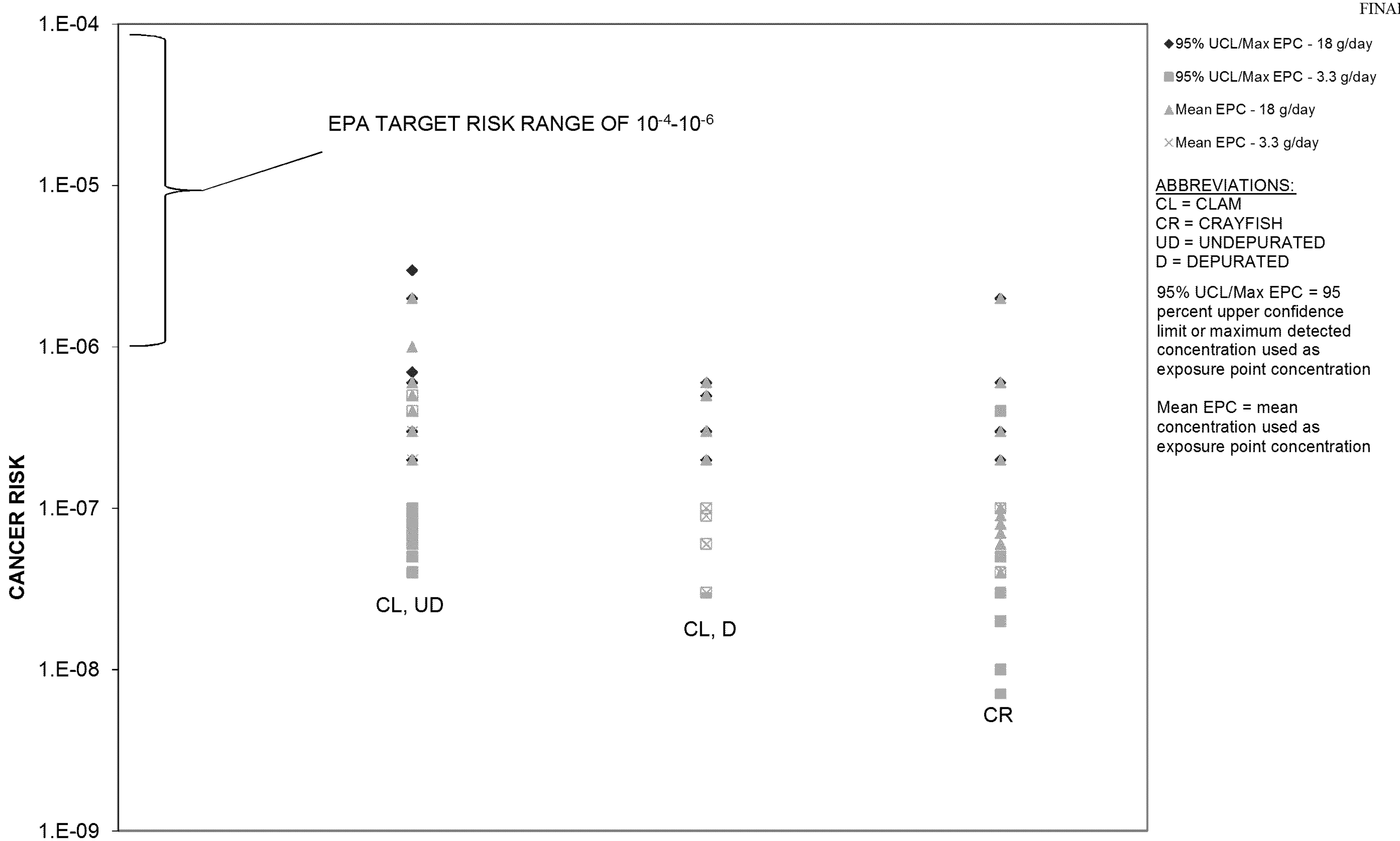

Figure 38
Non-Tribal Adult Cancer Risk From Total DDE in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

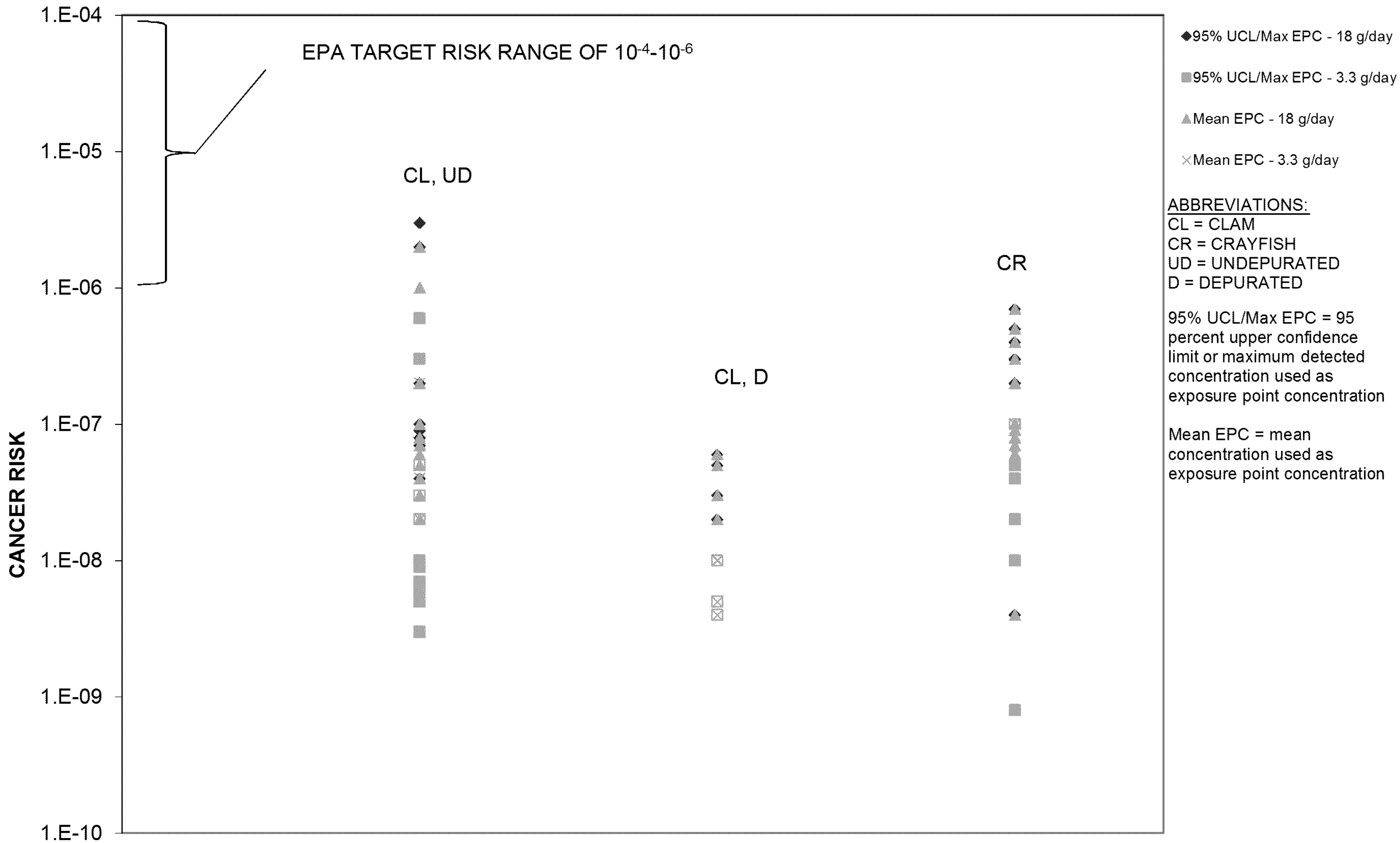

Figure 39
Non-Tribal Adult Cancer Risk From Total DDT in Shellfish Tissue

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

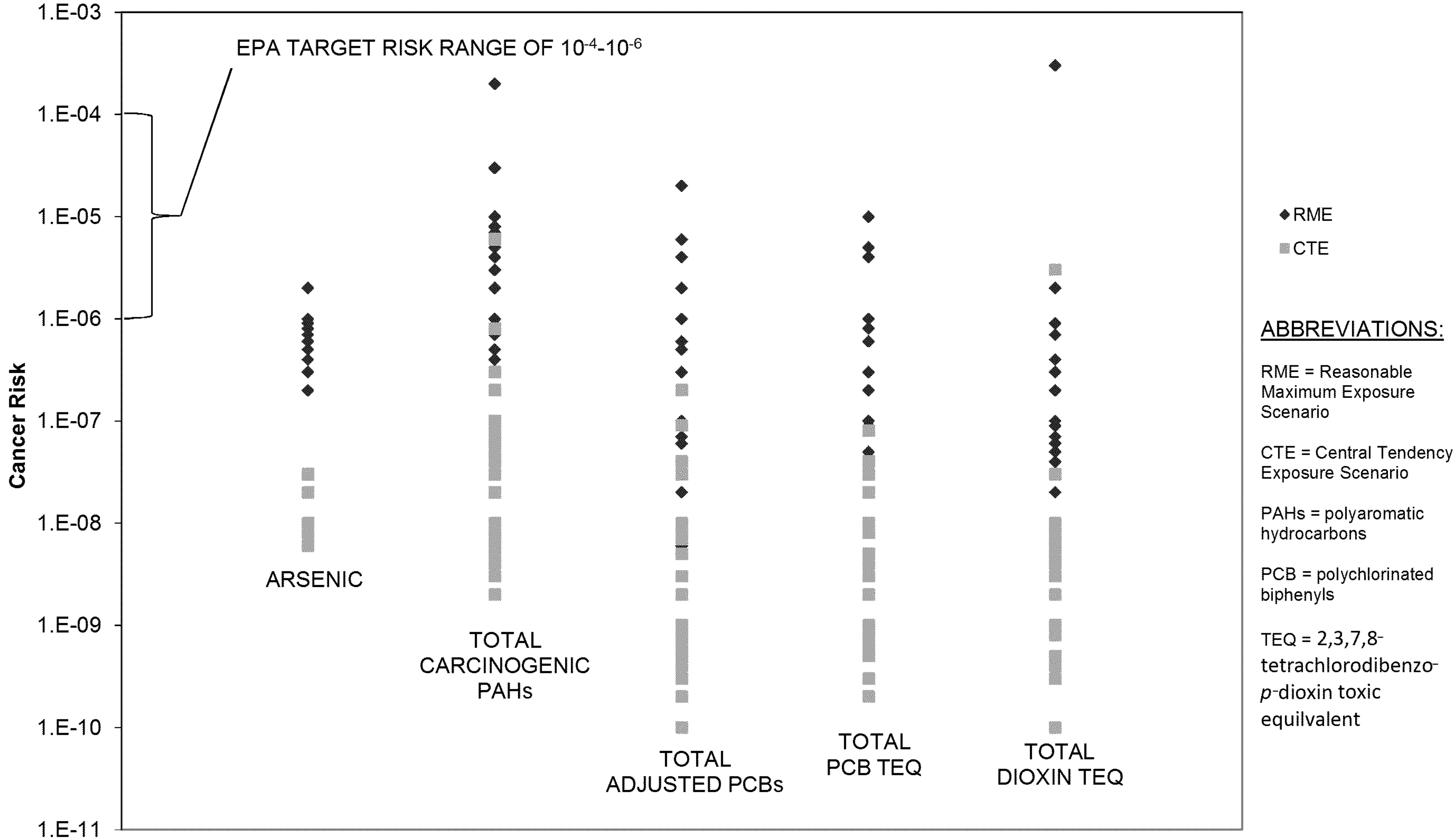

Figure 40
Tribal Fisher Cancer Risk from Arsenic, Total Carcinogenic PAHs, Total PCBs, Total PCB TEQ, and Total Dioxin TEQ in In-Water Sediment

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

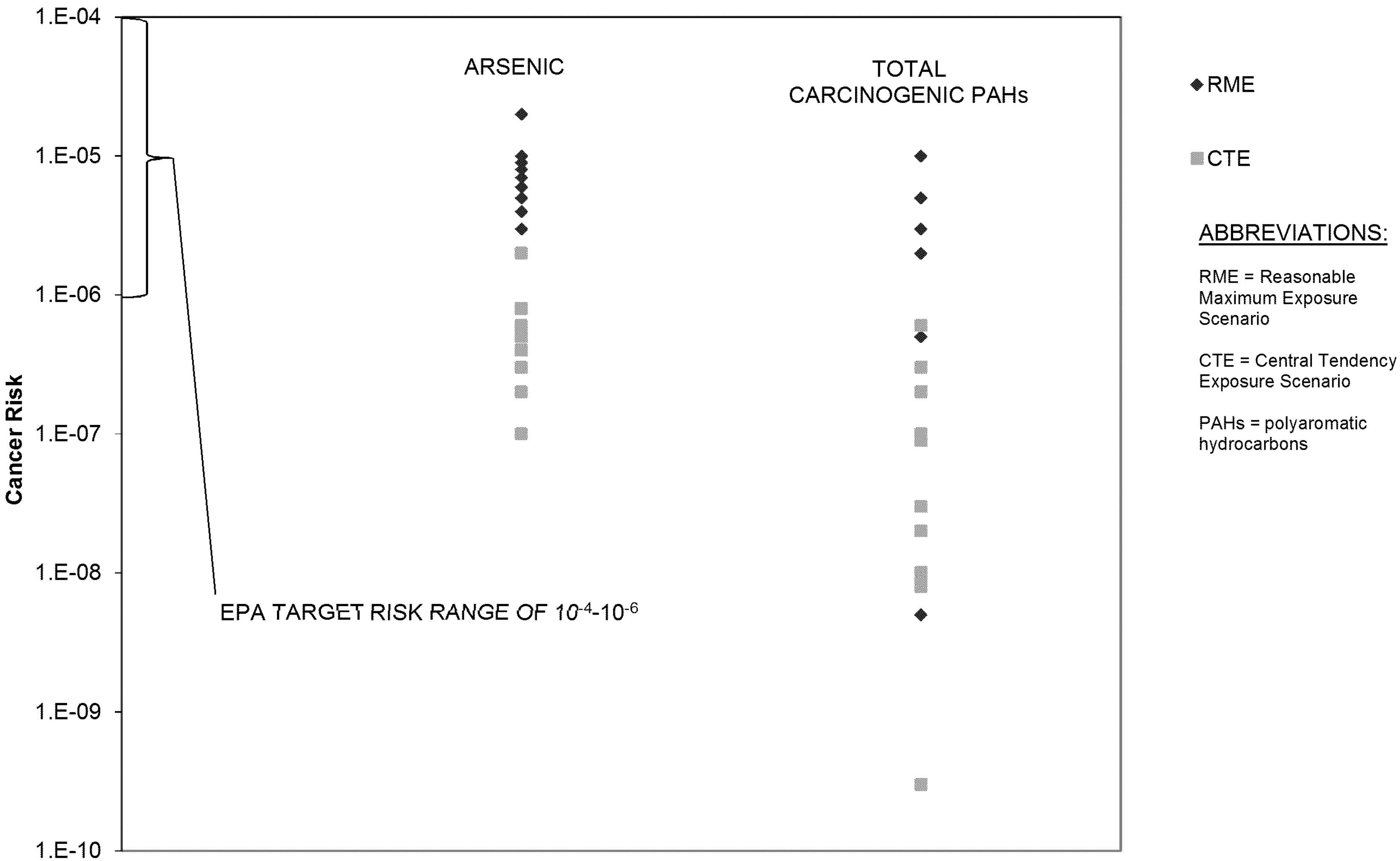

Figure 41
Tribal Fisher Cancer Risk from Arsenic and Total Carcinogenic PAHs in Beach Sediment

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

Table 1. Uncertainties Evaluated in the Baseline Human Health Risk Assessment

Uncertainty	Magnitude/ Severity of Uncertainty	Significance to Risk Management Decisions	More Likely to Result in Over- or Under-Estimation of Risk?
Data Evaluation			
Use of target species to represent all types of biota consumed	Medium	Low	Over
Source of contaminants for anadromous and wide-ranging fish species	Medium	Low	Over
Use of only whole body or only fillet samples to represent all fish consumption	Medium	Low	Over
Use of undepurated tissue to represent clam consumption	Medium	Medium	Over
Use of different tissue types to assess the same contaminant	Low	Low	Either
Detection limits that are above analytical concentration goals	Medium	Low	Under
Removal of Non-Detected Results Greater Than the Maximum Detected Concentration for a Given Exposure Area	Medium	Low	Either
Using N-qualified data	Medium	Low	Over
Using one-half the detection limit for non-detect results in summed analytes	Low	Low	Either
Contaminants that were not analyzed in certain samples	Medium	Low	Either
Contaminants that were not included as analytes	Low	Low	Under
Contaminants that were analyzed but not included in the BHHRA	Low	Low	Under
Data Not Included in BHHRA due to Collection Date	Medium	Low	Either
Compositing methods for biota and beach sediment sampling	Low	Low	Either
Mislabeling of smallmouth bass fish sample	Low	Low	Neither
Use of DEQ RBCs for petroleum hydrocarbon screening values	Low	Low	Under
Selection of Tissue COPCs based on detection of an analyte	Medium	Medium	Over
Exposure Assessment			
Model applicability	Medium	Low	Over
Subsurface sediment exposure	Medium	Low	Under
Exposure Scenarios			
Human Milk Consumption	Medium	High	Neither
Shellfish consumption	High	High	Over
Wet suit divers	High	High	Over
Hypothetical Domestic Water Use	High	High	Over
Potentially Complete and Insiginificant Exposure Pathways	Low	Low	Under
Exposure Factors			
Exposure parameters for sediment exposure scenarios	High	Medium/Low	Over
Exposure parameters for surface water and groundwater seep exposure scenarios	High	Low	Over
Exposure parameters for tissue ingestion scenarios	High	High	Over
Assumptions about a multiple-species diet	Medium	Low	Neither
Exposure Point Concentrations			
Using 5-10 samples to calculate the 95% UCL on the mean	Medium	Low	Under
Nondetects greater than the maximum detected concentrations	High	Low	Over
Using the maximum concentration to represent exposure	High	High	Over
Possible effects of preparation and cooking methods	Medium	Medium	Over
Assumptions about arsenic speciation	Low	Low	Under
Polychlorinated biphenyls (Aroclor vs. Congener analysis)	Low	Medium	Neither
Bioavailability of Contaminants	Medium	Low	Over
Smallmouth bass exposure areas	Low	Low	Neither
Surface water EPCs	Low	Low	Neither

Table 1. Uncertainties Evaluated in the Baseline Human Health Risk Assessment

Uncertainty	Magnitude/ Severity of Uncertainty	Significance to Risk Management Decisions	More Likely to Result in Over- or Under-Estimation of Risk?
Toxicity Assessment			
Early life exposure to carcinogens	Low	Low	Under
Lack of toxicity values for delta-hexachlorocyclohexane and titanium	High	Low	Under
Use of toxicity values from surrogate contaminants for some contaminants that lack toxicity values	Medium	Low	Either
Toxicity values for chromium	Medium	Low	Neither
Toxicity values for polychlorinated biphenyls and applicability to environmental data	Medium	Low	Over
Risk Characterization			
Risks from cumulative or overlapping scenarios	Medium	Low	Over
Risks from background	Medium	High	Over
Risks from lead exposure	Medium	Medium	Over
Future risks	Medium/High	Low	Either

Notes:
BHHRA baseline human health risk assessment
COPC contaminant of potential concern
DEQ Oregon Department of Environmental Quality
EPC exposure point concentration
RBC risk-based concentration
UCL upper confidence limit on the mean

Table 2. Summary of PCB Concentration Reduction Based on Preparation and Cooking[a]

Species[b]	Activity		Reduction (%)
Carp	Skin-off & deep frying		37
	Skin-off & deep frying		32
	Skin-off & deep frying		32
	Skin-off & pan frying		25
	Skin-off & pan frying		19
	Skin-off & pan frying		37
	Skin-on & deep frying		38
	Skin-on & deep frying		16
	Skin-on & deep frying		67
	Skin-on & pan frying		22
	Skin-on & pan frying		42
	Skin-on & pan frying		31
Chinook Salmon	Skin-off & baking		38
	Skin-off & baking		48
	Skin-off & baking		29
	Skin-off & charbroiling		44
	Skin-off & charbroiling		62
	Skin-off & charbroiling		33
	Skin-off & charbroiling, scoring		46
	Skin-off & charbroiling, scoring		52
	Skin-off & charbroiling, scoring		44
	Skin-off & canning		36
	Skin-off & canning		33
	Skin-off & canning		39
	Skin-on & baking		33
	Skin-on & baking		49
	Skin-on & baking		25
	Skin-on & charbroiling		40
	Skin-on & charbroiling		40
	Skin-on & charbroiling		44
	Skin-on & charbroiling, scoring		49
	Skin-on & charbroiling, scoring		61
	Skin-on & charbroiling, scoring		37
Smallmouth Bass	Trimming		64
	Baking		16
	Frying		74
	Trimming & cooking		80
		Minimum	16
		Maximum	80
		Average	40.91891892

Notes:

a Summary of information presented in Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2, Appendix C, Table C-1 (EPA 2000). Reductions are based on standard fillet.

b Only species included in the risk assessment are presented.

Table 3. Contaminants Potentially Posing Unacceptable Risks for Human Health

	BHHRA Exposure Medium and Scenario																																	
	Beach Sediment							Surface Water							In-Water Sediment												Fish Tissue						Shellfish	
Contaminant	Adult Recreational Beach User	Child Recreational Beach User	Dockside Worker	Low Frequency Fisher	High Frequency Fisher	Tribal Fisher	Transient	Adult Recreational Beach User	Child Recreational Beach User	Transient	Diver in Wet Suit	Diver in Dry Suit	Adult Resident, Hypothetical Drinking Water Scenario	Child Resident, Hypothetical Drinking Water Scenario	In-Water Worker	Low Frequency Fisher	High Frequency Fisher	Tribal Fisher	Diver in Wet Suit	Diver in Dry Suit	Ingestion of Human Milk (In-Water Worker)	Ingestion of Human Milk (Low Frequency Fisher)	Ingestion of Human Milk (High Frequency Fisher)	Ingestion of Human Milk (Tribal Fisher)	Ingestion of Human Milk (Diver in Wet Suit)	Ingestion of Human Milk (Diver in Dry Suit)	Adult Consumption	Child Consumption	Adult Tribal Consumption	Child Tribal Consumption	Ingestion of Human Milk (Non-tribal Consumption)	Ingestion of Human Milk (Tribal Consumption)	Adult Consumption	Ingestion of Human Milk (Non-tribal Consumption)
Metals																																		
Antimony																											+[a]	+[a]	+[b]	+				
Arsenic	X[ab]	X[b]		X[b]	X[b]	O							X	X			X[ab]	X[b]									O	O	#	O			O	
Chromium, hexavalent													X[ab]	X[a]																				
Lead[d]																											X[a]	X	X	X				
Mercury																											+	+	+	+				
Selenium																											+[abc]	+[a]						
Zinc																												+[abc]						
PAHs																																		
Benzo(a)anthracene		X[ab]	X[ab]										O[a]	O		X[ab]	X[ab]	X[ab]	X[ab]								X[abc]	X[ac]					O	
Benzo(a)pyrene		O[b]	O[a]		X[ab]	X[b]					X[ab]		#	#	X[ab]	O[b]	O[b]	O	O[b]	X[ab]							O	O	X[b]	X[b]			#	
Benzo(b)fluoranthene		X[ab]	X[ab]										X[ab]	O[a]		X[ab]	X[ab]	X[ab]	X[ab]									X[ac]					O	
Benzo(k)fluoranthene																																	X[ac]	
Dibenzo(a,h)anthracene		X[ab]	X[ab]										O	O		X[ab]	X[ab]	X[ab]	X[ab]								X[bc]	X					O	
Indeno(1,2,3-cd)pyrene		X[ab]	X[ab]										O[a]	O		X[ab]	X[ab]	X[ab]	X[ab]									X[c]					X	
Total Carcinogenic PAHs	X[ab]	O	O[a]	X[ab]	X[ab]	X[b]					X[ab]	X[ab]	#	#	X[ab]	O[b]	O[b]	#	O[b]	X[ab]							O	O	X	X			#	
Phthalates																																		
Bis(2-ethylhexyl)phthalate																											#	#	O	X				
SVOCs																																		
Hexachlorobenzene																											#	O	O	X				
Phenols																																		
Pentachlorophenol																																	X[ac]	
Polychlorinated Biphenyls																																		
Total PCBs																X[ab]	X[ab]	O[b]	X[ab]		+[ab]	X[ab]	X[ab]	O[b]	X[ab]		#	#	#	#	#	#	#	#
Total PCB TEQ																X[ab]	X[ab]	X[b]	X[ab]			X[ab]	X[ab]	X[b]	X[ab]		#	#	#	#	#	#	O	O
Dioxin/Furan																																		
Total Dioxin TEQ															O[ab]	O[ab]	O[ab]	#	O[ab]	X[ab]	O[ab]	O[ab]	O[ab]	#	O[ab]	X[ab]	#	#	#	O	#	#	#	#
Total TEQ															O[ab]	O[ab]	O[ab]	#	O[ab]	X[ab]							#	#	#	#			#	
Pesticides																																		
Aldrin																											X[c]						X[a]	
Dieldrin																											O	O	X	X			X[c]	
Heptachlor Epoxide																											X[abc]							
Total Chlordane																											O	X	X	X[b]				
Total DDD																											O	O	O	X			X[c]	
Total DDE																											O	O	O	X			X[c]	
Total DDT																											O	O	O	X			X[ac]	
Total DDX																															X			
Herbicides																																		
MCPP														+[ab]																				
Polybrominated Diphenyl Ethers																											+	+			+			

Notes:

Groundwater seep exposure resulted in no cancer or noncancer exceedances of target risk levels.
Shading indicates an exceedance of a hazard quotient of 1 for at least one BHHRA scenario.

X Contaminant exceeds cancer risk of 1 x 10^{-6} or a hazard quotient of 1 for at least one BHHRA scenario.
O Contaminant exceeds cancer risk of 1 x 10^{-5} or a hazard quotient of 1 for at least one BHHRA scenario.
\# Contaminant exceeds cancer risk of 1 x 10^{-4} or a hazard quotient of 1 for at least one BHHRA scenario.
\+ Contaminant exceeds a hazard quotient of 1 for at least one BHHRA scenario, but does not exceed a cancer risk of 1 x 10^{-6}.
a Status is result of target risk or hazard exceedance for two or fewer exposure points.
b Status is result of target risk or hazard exceedance for 95% UCL/Maximum scenario only.
c Status is result of target risk or hazard exceedance only for the highest ingestion rate.
d Status for lead is based on results of predicted blood lead levels.

BHHRA baseline human health risk assessment
DDD dichlorodiphenyldichloroethane
DDE dichlorodiphenyldichloroethylene
DDT dichlorodiphenyltrichloroethane
DDX total of six DDT congeners
MCPP 2-(2-Methyl-4-chlorophenoxy)propionic acid
PAH polycyclic aromatic hydrocarbon
PCB polychlorinated biphenyl
TEQ 2,3,7,8-TCDD toxic equivalent

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD.

Table 4. Summary of Considerations in Risk Management Recommendations for Fish Consumption

Contaminant	Primary contributor to risk	Spatial scale of risk exceedances	Magnitude of risk exceedances	Contribution of background to risks	Frequency of exceedences	Uncertainties in risk estimates
Polychlorinated Biphenyls	+	+	+			
Dioxin/Furans	+	+	+			
Metals						
Arsenic			-	-		
Antimony					-	-
Lead					-	-
Mercury				-		
Selenium			-		-	
Zinc			-		-	
Bis(2-ethylhexyl)phthalate					-	-
PAHs			-			
Hexachlorobenzene			-			
Pesticides						
Aldrin			-		-	
Dieldrin			-			
Heptachlor Epoxide			-		-	
Total Chlordane			-			
Total DDD			+			
Total DDE			+			
Total DDT			+			
Polybrominated Diphenyl Ethers				-		-

Notes:
+ Consideration in recommending contaminant as COC
- Consideration in not recommending contaminant as COC

COC Contaminant of Concern
DDD dichlorodiphenyldichloroethane
DDE dichlorodiphenyldichloroethylene
DDT dichlorodiphenyltrichloroethane
PAH polycyclic aromatic hydrocarbon

Table 5. PCB Concentrations in the Study Area Compared to Regional Tissue Studies

Species	Number of Samples	Average Total PCBs			
		Fillet Without Skin	Fillet With Skin	Whole Body	Units[a]
Portland Harbor Study Area[b]					
Common Carp	9, 15	-	2521	2757	µg/kg
Smallmouth Bass	18, 32	-	166	1053	µg/kg
Brown Bullhead[c]	6	363	-	511	µg/kg
Black Crappie[c]	4	-	24	164	µg/kg
Portland Harbor Upstream[d]					
Smallmouth Bass	6	-	-	169	µg/kg
Brown Bullhead	3	-	-	33	µg/kg
Columbia River Basin[e]					
White Sturgeon[f]	16, 8	120	-	173	µg/kg
Walleye	3	-	30	135	µg/kg
Mountain Whitefish	12	-	190	123	µg/kg
Largescale Sucker	19, 23	-	52	78	µg/kg
Bridgelip Sucker	0, 3	-	-	70	µg/kg
Rainbow Trout	7, 12	-	33	32	µg/kg
Mid-Willamette[g]					
Smallmouth Bass	10, 0	-	26	-	µg/kg
Carp	5, 20	-	71	146	µg/kg
Pikeminnow	8, 16	-	33	86	µg/kg
Largemouth Sucker	8	-	ND	96	µg/kg

Notes:

a Units are on a wet-weight basis
b Results are Study Area-wide averages for total PCBs as congeners, except where noted.
c Concentrations in fillet are total PCBs as Aroclors (congener data are not available).
d Results are averages for total PCBs as congeners in fish tissue samples collected upstream (i.e., river miles 20 to 28) of the Study Area.
e Columbia River Internation Fish Commision, Columbian River Basin Fish Contaminant Survey. 1996-1998. Results are for total PCBs as Aroclors.
f White sturgen samples are individual fish analyzed as fillets without skin.

g Human Health Risk Assessment of Chemical Contaminants in Four Fish Species From the Middle Willamette River, Oregon. November 2000. Results are for total PCBs as Aroclors.

\- designated tissue type not evaluated in study
µg/kg micrograms per kilogram
ND non-detect
PCB polychlorinated biphenyl

Table 6. Lead Concentration Present in Sediment

River Mile[a]	Lead Concentration in units of mg/kg[b]		
	Mean	Min	Max
1	11.82	3.74	27.7
2	19.3	2.2	110
3	19.11	5	204
4	64.14	2.64	1950
5	32.41	4.7	332
6	124.7	3.32	13400
7	38.49	3.67	1290
8	49.42	3.07	956
9	37.29	4.59	936
10	27.76	9.73	233
11	31.28	8.39	179
Study Area-Wide	41.42909091	2.2	13400

Notes:

a Data evaluated included data between river miles 1 and 11 inclusive, excluding Multnomah Channel. Non-detected results were removed from the dataset.

b Data statistics calculated using ProUCL v.4.0

mg/kg milligrams per kilogram

Table 7. Selenium Detection Limits in Tissue Samples of Smallmouth Bass

Tissue Type	Detection Limit	Units	TTL[a]	Units	Detects	Non-Detects
Whole body	0.17 - 0.3	mg/kg	1.3	mg/kg	4	34
Fillet	0.1 - 0.3	mg/kg	1.3	mg/kg	1	22

Notes:
a TTL was calculated based on a non-tribal child with an ingestion rate of 60 g/day

mg/kg milligrams per kilogram
TTL target tissue level

Table 8. Bis 2-Ethylhexyl Phthalate Concentration in Small Mouth Bass[a]

Sample Location	BEHP Concentration (µg/kg)	
	Whole Body[b]	Fillet
SB02E	66 UT	66 U
SB03E	480 UT	66 U
SB03W	340 UT	66 U
SB04E	320 UT	66 UT
SB04W	66 UT	66 U
SB05W	66 UT	66 U
SB06E	66 UT	66 U
SB06W	100 JT	93 J
SB07E	66 UT	66 U
SB07W	66 UT	66 U
SB08E	66 UT	66 U
SB08W	140 UT	66 U
SB09E	R	130 J
SB09W	66 UT	66 U
SB010E	2800 T	66 U
SB010W	44 JT	69 J
SB011E	66 UT	66 U
SB011W	2800 T	66 U

Notes:
a Analytical results from Round 3 sampling event.
b Whole body concentrations calculated from body without fillet and fillet data.

BEHP bis 2-ethylhexyl phthalate
E east
J Estimate
µg/kg micrograms per kilogram
R Rejected
T Value is calculated
U Not detected at value shown
JT and UT Combined qualifiers based on above definitions
W west

Table 9. Summary of PBDE Regional Tissue Data[a]

BDE 47 (2,2',4,4'-Tetrabromodiphenyl ether)

Study	Fish Species	Tissue Type	Total Number of Samples	Percent Detected	Minimum Detected	Maximum Detected
WDOE, Lower Columbia River (2005)	Peamouth	Fillets, skin on	1	100%	7.1	7.1
WDOE, Lower Columbia River (2005)	Northern pikeminnow	Fillets, skin on	1	100%	13	13
WDOE, Lower Columbia River (2005)	Largescale sucker	Fillets, skin on	1	100%	25	25
WDOE, Middle Columbia River (2005)	Yellow perch	Fillets, skin on	1	0%	ND	ND
WDOE, Middle Columbia River (2005)	Channel catfish	Fillets, no skin	1	100%	11	11
WDOE, Middle Columbia River (2005)	Largescale sucker	Fillets, skin on	1	100%	8.2	8.2
WDOE, Yakima River (2005)	Common carp	Fillets, skin on	1	100%	2.7	2.7
WDOE, Yakima River (2005)	Largescale sucker	Fillets, skin on	1	100%	20	20
WDOE, Yakima River (2005)	Smallmouth bass	Fillets, skin on	1	100%	6.2	6.2
WDOE, Yakima River (2005)	Northern pikeminnow	Fillets, skin on	1	100%	6.6	6.6
LWG collected (2007), EPA analysis (2009)	Common carp	Fillets, skin on	11	100%	19	57
LWG collected (2007), EPA analysis (2009)	Smallmouth bass	Fillets, skin on	19	32%	3	6
DEQ, Willamette River Watershed (2008)	Smallmouth bass	Fillets, no skin	4	100%	3.10 J	9.62 J
DEQ, Willamette River Watershed (2008)	Largemouth bass	Fillets, no skin	1	100%	6.89 J	6.89 J
DEQ, Willamette River Watershed (2008)	Northern pikeminnow	Fillets, no skin	5	100%	2.29 J	10.4 J
WDOE, Spokane River (2005)	Bridgelip sucker	Fillets, skin on	1	100%	59	59
WDOE, Spokane River (2005)	Rainbow trout	Fillets, skin on	1	100%	182	182
WDOE, Spokane River (2005)	Mountain whitefish	Fillets, skin on	1	100%	443	443

BDE 99 (2,2',4,4',5-Pentabromodiphenyl ether)

Study	Fish Species	Tissue Type	Total Number of Samples	Percent Detected	Minimum Detected	Maximum Detected
WDOE, Lower Columbia River (2005)	Peamouth	Fillets, skin on	1	0%	ND	ND
WDOE, Lower Columbia River (2005)	Northern pikeminnow	Fillets, skin on	1	0%	ND	ND
WDOE, Lower Columbia River (2005)	Largescale sucker	Fillets, skin on	1	0%	ND	ND
WDOE, Middle Columbia River (2005)	Yellow perch	Fillets, skin on	1	0%	ND	ND
WDOE, Middle Columbia River (2005)	Channel catfish	Fillets, no skin	1	100%	5.4	5.4
WDOE, Middle Columbia River (2005)	Largescale sucker	Fillets, skin on	1	0%	ND	ND
WDOE, Yakima River (2005)	Common carp	Fillets, skin on	1	0%	ND	ND
WDOE, Yakima River (2005)	Largescale sucker	Fillets, skin on	1	0%	ND	ND
WDOE, Yakima River (2005)	Smallmouth bass	Fillets, skin on	1	100%	1.1	1.1
WDOE, Yakima River (2005)	Northern pikeminnow	Fillets, skin on	1	0%	ND	ND
LWG collected (2007), EPA analysis (2009)	Common carp	Fillets, skin on	11	0%	ND	ND
LWG collected (2007), EPA analysis (2009)	Smallmouth bass	Fillets, skin on	19	0%	ND	ND
DEQ, Willamette River Watershed (2008)	Smallmouth bass	Fillets, no skin	4	75%	0.252	2.52 J
DEQ, Willamette River Watershed (2008)	Largemouth bass	Fillets, no skin	1	100%	1.38 J	1.38 J
DEQ, Willamette River Watershed (2008)	Northern pikeminnow	Fillets, no skin	5	100%	0.0571	1.39 J
WDOE, Spokane River (2005)	Bridgelip sucker	Fillets, skin on	1	100%	0.46	0.46
WDOE, Spokane River (2005)	Rainbow trout	Fillets, skin on	1	100%	172	172
WDOE, Spokane River (2005)	Mountain whitefish	Fillets, skin on	1	100%	449	449

BDE 153 (2,2',4,4',5,5'-Hexabromodiphenyl ether)

Study	Fish Species	Tissue Type	Total Number of Samples	Percent Detected	Minimum Detected	Maximum Detected
WDOE, Lower Columbia River (2005)	Peamouth	Fillets, skin on	1	100%	0.32 J	0.32 J
WDOE, Lower Columbia River (2005)	Northern pikeminnow	Fillets, skin on	1	100%	0.19 J	0.19 J
WDOE, Lower Columbia River (2005)	Largescale sucker	Fillets, skin on	1	100%	0.53	0.53
WDOE, Middle Columbia River (2005)	Yellow perch	Fillets, skin on	1	0%	ND	ND
WDOE, Middle Columbia River (2005)	Channel catfish	Fillets, no skin	1	100%	0.74 J	0.74 J
WDOE, Middle Columbia River (2005)	Largescale sucker	Fillets, skin on	1	100%	0.18 J	0.18 J
WDOE, Yakima River (2005)	Common carp	Fillets, skin on	1	0%	ND	ND
WDOE, Yakima River (2005)	Largescale sucker	Fillets, skin on	1	100%	0.45	0.45
WDOE, Yakima River (2005)	Smallmouth bass	Fillets, skin on	1	100%	0.13 J	0.13 J
WDOE, Yakima River (2005)	Northern pikeminnow	Fillets, skin on	1	100%	0.23 J	0.23 J
LWG collected (2007), EPA analysis (2009)	Common carp	Fillets, skin on	11	64%	0.08 J	0.19 J
LWG collected (2007), EPA analysis (2009)	Smallmouth bass	Fillets, skin on	19	79%	0.06 J	0.5 J
DEQ, Willamette River Watershed (2008)	Smallmouth bass	Fillets, no skin	4	100%	0.0466	0.128
DEQ, Willamette River Watershed (2008)	Largemouth bass	Fillets, no skin	1	100%	0.0583	0.0583
DEQ, Willamette River Watershed (2008)	Northern pikeminnow	Fillets, no skin	5	100%	0.0194	0.38 J
WDOE, Spokane River (2005)	Bridgelip sucker	Fillets, skin on	1	100%	2.5	2.5
WDOE, Spokane River (2005)	Rainbow trout	Fillets, skin on	1	100%	7.5	7.5
WDOE, Spokane River (2005)	Mountain whitefish	Fillets, skin on	1	100%	17	17

Notes:

a all concentrations are presented in micrograms per kilogram

DEQ = Oregon Department of Environmental Quality.
EPA = United States Environmental Protection Agency.
J = Denotes estimated concentration.
LWG = Lower Willamette Group.
ND = Not detected.
PBDE = Polybrominated diphenylether.
WDOE = Washington Department of Ecology.

Table 10. Summary of Considerations in Risk Management Recommendations for Shellfish Consumption

Contaminant	Primary contributor to risk	Spatial scale of risk exceedances	Magnitude of risk exceedances	Contribution of background to risks	Frequency of exceedences	Uncertainties in risk estimates
Polychlorinated Biphenyls	+	+	+			
Dioxin/Furans	+		+			
Arsenic			-	-		
PAHs	+		+			
Pentachlorophenol			-		-	
Pesticides						
Aldrin			-		-	
Dieldrin			-		-	
Total DDD			-		-	
Total DDE			-		-	
Total DDT			-		-	

Notes:
+ Consideration in recommending contaminant as COC
- Consideration in not recommending contaminant as COC

COC Contaminant of Concern
DDD dichlorodiphenyldichloroethane
DDE dichlorodiphenyldichloroethylene
DDT dichlorodiphenyltrichloroethane
PAH polycyclic aromatic hydrocarbon

Table 11. Summary of Considerations in Risk Management Recommendations for In-Water Sediment

Contaminant	Primary contributor to risk	Spatial scale of risk exceedances	Magnitude of risk exceedances	Contribution of background to risks	Frequency of exceedences	Uncertainties in risk estimates
Polychlorinated Biphenyls			-			
Dioxin/Furans	+		+			
Arsenic			-	-		
PAHs	+		+			

Notes:
+ Consideration in recommending contaminant as COC
- Consideration in not recommending contaminant as COC

COC Contaminant of Concern
PAH polycyclic aromatic hydrocarbon

Table 12. Summary of Considerations in Risk Management Recommendations for Beach

Contaminant	Primary contributor to risk	Spatial scale of risk exceedances	Magnitude of risk exceedances	Contribution of background to risks	Frequency of exceedences	Uncertainties in risk estimates
Arsenic			-	-		
PAHs			-			-

Notes:
+ Consideration in recommending contaminant as COC
- Consideration in not recommending contaminant as COC

COC Contaminant of Concern
PAH polycyclic aromatic hydrocarbon

Table 13. Recommended Contaminants of Concern and Exposure Pathways for the Feasibility Study

	BHHRA Exposure Pathway						
Contaminant	In-Water Sediment, Direct Contact	Fish Consumption	Shellfish Consumption	Beach Sediment, Direct Contact	Groundwater Seep, Direct Contact	Surface Water, Direct Contact	Infant Consumption of Human Milk
Carcinogenic PAHs	X[a]		X				
PCBs		X	X				
Dioxins/furans	X[b]	X	X				
Total DDx		X[c]					

Notes:

a COC for river mile 6 west only
b COC for river mile 7 west only
c COC for river mile 7 only

X Contaminant/pathway is recommended as a COC in the FS.
BHHRA baseline human health risk assessment
DDD dichlorodiphenyldichloroethane
DDE dichlorodiphenyldichloroethylene
DDT dichlorodiphenyltrichloroethane
DDx sum of the six DDT congeners (2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT)
PCB polychlorinated biphenyl
PAH polycyclic aromatic hydrocarbon

LWG
LOWER WILLAMETTE GROUP

PORTLAND HARBOR RI/FS

RISK MANAGEMENT RECOMMENDATIONS

ATTACHMENT 2: SUMMARY OF ECOLOGICAL RISK ASSESSMENT AND RISK MANAGEMENT RECOMMENDATIONS

FINAL

RECOMMENDED FOR INCLUSION IN ADMINISTRATIVE RECORD

July 22, 2011

Prepared for
The Lower Willamette Group

Prepared by
Windward Environmental, LLC

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

LIST OF ACRONYMS

AOC	area of concern
AOPC	area of potential concern
ACR	acute-to-chronic ratio
AWQC	ambient water quality criterion
BEHP	bis(2-ethylhexyl) phthalate
BERA	Baseline Ecological Risk Assessment
BHRRA	Baseline Human Health Risk Assessment
BMR	biomagnification regressions
CERCLA	Comprehensive Environmental Recovery, Cleanup and Liability Act
COC	contaminant of concern
COI	contaminant of interest
COPC	contaminant of potential concern
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEQ	Department of Environmental Quality
DL	detection limit
EPA	US Environmental Protection Agency
ERAGS	Ecological Risk Assessment Guidance for Superfund
FPM	floating percentile model
FS	feasibility study
HQ	hazard quotient
LOAEL	lowest-observed-adverse-effect level
LOE	line of evidence
LRM	logistic regression model
LWG	Lower Willamette Group
MQ	mean quotient
NOAEL	no-observed-adverse-effect level
PAHs	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
RAO	remedial action objective
RI	remedial investigation
RM	river mile
SLERA	screening level ecological risk assessment
SPI	sediment profile imaging
SSD	species sensitivity distribution
SQG	sediment quality guidelines
SQV	sediment quality value
SVOC	semivolatile organic compound
TBT	tributyltin
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ	toxic equivalent
TEF	toxic equivalency factors

LIST OF ACRONYMS (CONTINUED)

Total DDx	sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
TPH	total petroleum hydrocarbons
TRV	toxicity reference value
TZW	transition zone water
UCL	upper confidence limit
VOC	volatile organic compound
WOE	weight of evidence

1.0 INTRODUCTION

Section 2 of this document presents a summary of the ecological risk assessment and Section 3 presents the Lower Willamette Group's (LWG) ecological risk management recommendations. The risk assessment summary is based on findings in the Baseline Ecological Risk Assessment (BERA) and is based on Section 11 of the BERA; the risk management recommendations presented here were previously presented as Section 12 of the BERA (Windward 2011).

2.0 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

Risk estimates in this BERA were calculated following Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) guidance (U S Environmental Protection Agency [EPA] 1997, 1998) and EPA's Problem Formulation (see BERA Attachment 2). The conclusions of the BERA, along with those of the Baseline Human Health Risk Assessment (BHHRA), are intended to provide information to risk managers on potentially unacceptable risks predicted under current conditions of the Study Area, as well as information on possible future approaches for protecting human health and the environment.

Consistent with Ecological Risk Assessment Guidance for Superfund (ERAGS) (EPA 1997) the foregoing risk conclusions identified the receptor-contaminant of potential concern (COPC) pairs that, given the magnitude and extent of risk, are reasonably likely to result in adverse effects on the assessment endpoints selected to represent the valued ecological attributes of the Study Area. The remainder of Section 2 is organized as follows:

- Section 2.1 presents a summary by receptor group and line of evidence (LOE) of the 89[1] ecological COPCs identified as posing potentially unacceptable risk in this BERA based on hazard quotient (HQ) ≥ 1 for at least one receptor-LO E combination.
- Section 2.2 identifies COPCs identified as posing potentially unacceptable risks for ecological receptors in the Study Area that occur at concentrations similar to the sediment and surface water background levels[2] or to tissue concentrations in four fish receptor species (i.e., juvenile Chinook salmon, brown bullhead, smallmouth bass, and lamprey ammocoetes) collected from the upriver reach of the Willamette River (river mile [RM] 15.3 to RM 28.4).
- Section 2.3 combines the risk conclusions across all ecological receptor groups to provide a general overview of ecological risks and to identify the receptor-COPC pairs that, given the magnitude and extent of risk, are reasonably likely to result in adverse effects on the assessment endpoints.

It is important to note that Section 2 provides only a summary of risk assessment conclusions; additional details are provided in the BERA. Risk management recommendations from the LWG risk assessors to EPA risk managers, based on the results of the BERA, are presented in Section 3

[1] Ninety-one contaminants have HQs ≥ 1. Because petroleum compounds are not CERCLA contaminants, gasoline-range hydrocarbons and diesel-range hydrocarbons have been excluded from the final count even though they may be contributing to potentially unacceptable risk.
[2] Background concentrations for water and sediment are presented in the draft final remedial investigation (RI).

2.1 SUMMARY OF POTENTIALLY UNACCEPTABLE RISKS

Consistent with EPA Superfund ERAGS (EPA 1997, 1998), potentially unacceptable risks were identified through an iterative process of analyzing the exposure and effects data for the various chemicals and ecological receptors, with increasing realism at each step in the process. For most receptors, several LOEs were evaluated. For each LOE, risk characterization began with the screening level ecological risk assessment (SLERA) and progressed iteratively through the final step in the risk characterization. Throughout the process, chemical-receptor pairs that showed the potential for adverse effects were further analyzed and those that did not were screened out. The final step in the process reflects the most realistic risk estimates. Potentially unacceptable risks were identified for each receptor-LOE-COPC combination based on the final step in the risk characterization.

Exposure data in the final step of the risk analysis were evaluated at the scale over which the receptors are likely to be exposed and, where pertinent, the variety of potentially contaminated prey the receptor may consume. For the least mobile receptors (e.g., benthic macroinvertebrates, sculpin, aquatic plants), exposure is conservatively evaluated over areas no larger than the immediate area where samples were collected; for the most mobile receptors (e.g., white sturgeon, largescale sucker), the exposure areas encompass the entire Study Area. For moderately mobile receptors (e.g., smallmouth bass, mink) the Study Area is divided into several exposure areas each 1 to 3 miles long.

For all LOEs except sediment, numerical risk estimates were calculated as HQs. HQs were calculated separately for each receptor-LOE-COPC combination for each exposure area. Receptor-LOE-COPC combinations resulting in HQ $\geq$ 1 in the final step of the risk characterization in any exposure area were identified as posing potentially unacceptable risk. For the sediment LOE, a location was identified as posing potentially unacceptable risk to benthic invertebrates if the sediment was toxic or predicted to be toxic based on a sediment COPC concentration that exceeded a site-specific sediment quality value (SQV).

Those chemicals for which exposure or effects data were insufficient to evaluate the risk were also identified as posing potentially unacceptable risk, although risk is unknown. Risk to benthic organisms, including clams and crayfish, could not be evaluated for 78 sediment contaminants of interest (COIs) because either no relationship between sediment contaminants and toxicity was apparent in the site-specific dataset or too few data points were available to discern a relationship. Other contaminants that could not be evaluated for their contribution to benthic community risks include 27 tissue COIs, 19 surface water COIs, and 16 transition zone water (TZW) COIs. Risk to fish from a number of COIs could not be evaluated: 17 tissue-residue COIs, 11 dietary COIs, 5 surface water COIs, and 9 TZW COIs. Risk to birds and mammals from dietary exposure to 19 COIs could not be evaluated. Risk to amphibians and aquatic plants from 27 COIs (including 19 surface water COIs and 16 TZW COIs) could not be evaluated. As per agreement with EPA (LWG 2010), these

COIs are identified as chemicals for which no toxicity reference value (TRV) is available as well as chemicals whose maximum detection limit (DL) exceeded a TRV but whose detected values did not.

Risk assessments are, by design, conservative in the face of uncertainty. However, not all uncertainties create a conservative bias. Some examples of uncertainties that could lead to underestimation of risk include unavailability of exposure or effects data; existing TRVs that might underestimate risk for untested sensitive species; synergistic interactions among the multiple chemicals; and metabolic processes that increase the toxicity of accumulated chemicals.

Table 1 tallies the COPCs for each ecological receptor group. In total, 89 CERCLA contaminants were identified as posing potentially unacceptable risk in the BERA based on HQ $\geq$ 1 for at least one receptor-LOE combination.[3]

- **Benthic invertebrates** – Eighty-three COPCs were identified via one or more of the sediment, tissue-residue, surface water, and TZW LOEs.[4]
- **Fish** – Fifty nine COPCs were identified using the tissue-residue, dietary-dose, surface water, and TZW LOEs.[5]
- **Wildlife** – Twelve COPCs were identified for birds using the dietary-dose and tissue-residue (egg) LOEs, and six COPCs were identified for mammals using the dietary-dose LOE.
- **Amphibians** – Thirty-three COPCs were identified using the surface water and TZW LOEs.[6]
- **Aquatic plants** – Thirty-three COPCs were identified using the surface water and TZW LOEs.[7]

The spatial extent, magnitude and potential ecological significance of TRV exceedances and the concordance among LOEs were considered to determine risk conclusions for contaminants posing potentially unacceptable risk. The main

[3] Counts of COPCs with HQs $\geq$ 1 are based on HQs derived using alternative surface water TRVs for PCBs, 4,4'-DDT, and total DDx, as opposed to the AWQC-based TRVs.
[4] Eighty-five benthic invertebrate COPCs have HQs $\geq$ 1. Petroleum compounds are not CERCLA contaminants, and have been excluded from the final COPC count for sediment and TZW LOEs even though this chemical group may be contributing to potentially unacceptable risk.
[5] Sixty fish COPCs have HQs $\geq$ 1. Petroleum compounds are not CERCLA contaminants and have been excluded from the COPC count for the TZW LOE even though this chemical group may be contributing to potentially unacceptable risk.
[6] Thirty-four amphibian COPCs have HQs $\geq$ 1. Petroleum compounds are not CERCLA contaminants and have been excluded from the COPC count for the TZW LOE even though this chemical group may be contributing to potentially unacceptable risk.
[7] Thirty-four aquatic plant COPCs have HQs $\geq$ 1. Petroleum compounds are not CERCLA contaminants and have been excluded from the COPC count for the TZW LOE even though this chemical group may be contributing to potentially unacceptable risk.

conclusions of the BERA by receptor group are briefly summarized below in Section 2.3.

2.2 BACKGROUND AND UPRIVER CONCENTRATIONS

Sediment and water concentrations in the Study Area were compared to background.[8] For aluminum, dibutyl phthalate, benzyl alcohol, and alpha-endosulfan, background sediment upper confidence limits (UCLs) are the same as or higher than Study Area UCLs. The background surface water UCL concentration is higher than the Study Area UCL only for aluminum. Although fish tissue data from the upriver reach are insufficient to allow calculation of UCLs, their concentrations are similar to those in the Study Area for aluminum, mercury, and copper.

Background concentrations for sediment and surface water, and upriver concentrations for fish tissue provide context for Study Area risk predictions but were not used to discount risks or influence risk estimates. Where background concentrations exceed screening-level TRVs or upriver fish tissue concentrations exceed tissue TRVs, upriver or regional sources may be contributing to unacceptable risks in the Study Area.

2.3 ECOLOGICAL RISK CONCLUSIONS

The risk conclusions across all ecological receptor groups are combined and briefly summarized in this section to provide a general overview of ecological risks and to identify the receptor-COPC pairs that, given the magnitude and extent of risk, are reasonably likely to result in adverse effects on the assessment endpoints that were selected in the Problem Formulation to represent the valued ecological attributes of the Study Area. For example, this section (2.3) contains statements with qualitative adjectives like "limited" or "moderate" when describing the spatial extent of exposure to a COPC at concentrations yielding HQs ≥ 1. Statements such as, "uncertainty in the tissue-residue TRV is more likely to over- than underpredict risk" are made without repeating the supporting evidence. In cases such as these, the reader interested in the details should refer back to the risk conclusions section for the relevant receptor group in the BERA. The main conclusions of the BERA by receptor group are presented in Sections 2.3.1 through 2.3.5. Section 2.3 closes with a brief synopsis of potential future benthic community risks in erosional sections of the Study Area.

2.3.1 Benthic Invertebrate Community

COPCs occur at concentrations that are projected to pose unacceptable benthic risks for about 7% of the Study Area. Unlike other ecological receptors, for which risk was evaluated on a chemical-specific basis, risk to the benthic invertebrate community

[8] Background concentrations for water and sediment are presented in the draft final RI

was evaluated in large part by considering exposure to the mixture of chemicals present in the Study Area sediments, using toxicity tests and multivariate predictive models based on the toxicity test results. Point-by-point assessment of potential effects on benthic organisms using data from toxicity testing, modeling, and benthic tissue-residue analyses indicates that metals, tributyltin (TBT), polycyclic aromatic hydrocarbons (PAHs), several semivolatile organic compounds (SVOCs), two phenolic compounds, dibutylphthalate, total polychlorinated biphenyls (PCBs), the sum of all six DDT isomers (total DDx) , and other pesticides pose potentially unacceptable risk. Several other contaminants (total petroleum hydrocarbons [TPH], ammonia, and sulfides) may also contribute to potentially unacceptable risk at some areas. A weight of evidence (WOE) was assessed to identify contaminants that were most likely posing unacceptable risk. Based on that evaluation, the primary COPCs in sediment that likely pose potentially unacceptable risk to the benthic community or populations are PAHs, PCBs, and total DDx. Although other contaminants also contribute to potentially unacceptable risk, their distribution and magnitude of risk tends to be represented by the distribution and magnitude of primary COPCs. One exception is the certain contaminants associated with the localized TZW investigation areas. In these areas, volatile organic compounds (VOCs), cyanide, and perchlorate may also pose potentially unacceptable risks; however, these contaminants often co-occur with PAHs and DDx.

The phenolic compound 4-methylphenol may also be contributing to benthic community risk. The analysis conducted for the BERA shows that the sediment exposure pathway is sufficient to be of concern for 4-methylphenol. Widely distributed throughout the Study Area, this contaminant is found in both contaminated and otherwise uncontaminated areas. Methylated phenols are readily biodegraded under aerobic conditions, and 4-methylphenol is expected to have a half-life in sediment on the order of days. That 4-methylphenol was found suggests the presence of ongoing sources; however, whether and to what extent the source is degradation of historical contamination versus influx from ongoing point or non-point discharges is not known.

Sediment profile images of the surface sediment suggest that the physical environment (sediment grain size, transport regime, bottom slope) in the Study Area can explain the presence of early colonizing, transitional, and mature benthic communities in 90% of the images evaluated. In these cases, the successional stage matched the expected community structure based on the physical regime and habitat characteristics. In the vast majority of cases, mature benthic communities occurred in fine-grained depositional environments; early colonizing or transitional communities were found in less physically stable areas (for example, with steep slopes, active sediment transport, high rates of deposition, or physical disturbance). In the 31 (of 377) cases where the community successional stage was not as might be predicted by the physical environment, about two-thirds (19) occur between RM 5.0 and RM 9.0. The greatest combined area associated with potentially unacceptable risk to the benthic community was found in this same reach, suggesting possible chemical toxicity, among other potential factors, as the reason for the presence of lower successional stages. These qualitative results suggest that overall, the benthic community in the Study Area is typical of a large river system that is strongly influenced by physical processes. Impacts from sediment contamination appear to be limited to certain depositional areas that have received historical releases of contamination.

2.3.2 Fish

The fish assessment endpoints are survival, growth and reproduction of omnivorous, invertivorous, and piscivorous fish, as well as survival and growth of detritivorous fish. The assessment endpoints are based on protection and maintenance of populations and the communities in which they live, except for Pacific lamprey ammocoete and juvenile Chinook salmon, which, as special status species, are to be protected at the organism level.

PCBs were found to pose low risk to populations of piscivorous fish and the small-home-range invertivorous fish sculpin. PCB tissue-residue HQs ≥ 1 were calculated for smallmouth bass, northern pikeminnow, and sculpin samples from locations throughout the Study Area (max HQ = 9.4). HQs < 1 for juvenile Chinook salmon and peamouth show that risk to sculpin does not imply risk to invertivorous fish with larger home ranges. Together, the low Study Area-wide tissue-residue HQ of 1.6 for largescale sucker in combination with HQs < 1 for most omnivorous fish samples and with uncertainty in effects data indicate that risk to omnivorous fish is negligible.

The potential for adverse effects on all of the fish assessment endpoints from PCBs was assessed to be low: the other LOE for PCBs—surface water—resulted in HQs < 1,[9] tissue-residue HQs ≥ 1 occurred over only a moderate spatial extent (or in relatively few samples for large-home-range fish), and uncertainty in the tissue-residue TRV is more likely to overpredict than underpredict risk. The tissue-residue TRV for PCBs is conservative because it is based partially on uncertain toxicity data, including field data from contaminated sites where other contaminants were also present, suggesting that the TRV reflects toxicity from chemicals other than PCBs.

The spatial extent of dietary risk to juvenile Chinook salmon from cadmium encompasses a substantial portion of the Study Area. However, the assumption that juvenile Chinook consume benthic invertebrates, rather than the pelagic prey they are known to eat, overestimates exposure. The selected TRV also very likely overestimates risk because it is 3 orders of magnitude below the lowest salmon-specific no-observed-adverse-effect level (NOAEL).

The spatial extent of dietary and tissue-residue risk from copper to several fish (sculpin, juvenile Chinook salmon, Pacific lamprey ammocoetes, northern

[9] When calculated using the alternative TRV for protection of directly exposed aquatic organisms rather than the AWQC, which is based on protection of mink through dietary exposure.

pikeminnow, largescale sucker, and juvenile white sturgeon) also encompasses a substantial portion of the Study Area. The copper-fish TRVs are highly uncertain. The dietary TRV could not be replicated in subsequent studies, and the tissue-residue TRV is within the range of copper nutritional requirements for some (but not all) fish species. Furthermore, predictions of risk to fish based on tissue concentrations copper are highly uncertain because fish regulate this essential metal.

Several COPCs in TZW were identified as posing risk to individual fish, but not their populations. Benthic fish, including burrowing fish (lamprey ammocoetes) and fish that feed on benthic organisms (sculpin), have relatively low exposure to porewater compared with surface water because of their feeding habits and respiratory requirements. For this reason concentrations of COPCs in shallow TZW likely overestimate exposure, to an uncertain degree. Because TZW exceedances are localized, none of the TZW COPCs is likely to pose risk to Study Area benthic invertebrate or fish populations. However, 38 TZW COPCs,[10] 6 metals (barium, iron, manganese, sodium, vanadium, and zinc), 16 PAHs (2-methylnaphthalene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthtene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene), 2 SVOCs (1,2-dichlorobenzene, 1,4-dichlorobenzene), the pesticides 4,4′- dichlorodiphenyltrichloroethane (4,4′-DDT) and total DDx, 10 VOCs (benzene, carbon disulfide, chlorobenzene, chloroform, cis-1,2dichloroethene, ethylbenzene, o-xylene, toluene, total xylenes and trichloroethene), cyanide and perchlorate have high concentrations in localized areas that could adversely affect Pacific lamprey ammocoetes at those locations. The magnitude of risk to individual lamprey from these COPCs is unknown however, because the TRVs were derived to be protective of the most sensitive species and are likely to overpredict risk to Pacific lamprey which has been shown to have average or lower sensitivity than most aquatic species for several chemicals causing toxicity from different modes of action (Andersen et al. 2010). Three of the 38 COPCs (excluding petroleum hydrocarbons.) with HQs >10 are naturally occurring metals (barium, iron, and manganese) and there is substantial uncertainty as to whether their source is anthropogenic.

Risk to fish from other COPCs that resulted in HQs ≥ 1 in the final step of the risk characterization were found unlikely to result in ecologically significant adverse effects on the fish populations. The rationale for this conclusion is that TZW exposure assumptions likely overestimate risk, the TRV overestimates risk, and the great majority of samples result in HQs < 1 (indicating a limited spatial extent of potentially unacceptable risk).

[10] Petroleum hydrocarbons were evaluated as an uncertainty and gasoline-range aliphatic hydrocarbons (C10-C12) have HQ > 10 over a limited spatial extent and also pose potentially unacceptable risk to individual lamprey.

2.3.3 Wildlife

The avian assessment endpoints are survival, growth, and reproduction of invertivorous, omnivorous, and piscivorous birds. The mammalian assessment endpoint was survival, growth, and reproduction of aquatic-dependent mammals. The assessment endpoints are based on protection and maintenance of populations and the communities in which they live, except for threatened or endangered species, which are to be protected at the organism level.

PCBs pose the primary risk. Mink and river otter HQs ≥ 1 throughout the Study Area (mink HQ = 19 to 33, river otter HQ = 21 to 31) indicate that PCBs pose ecologically significant risk of reduced reproductive success to populations of both receptors in the Study Area. While the BERA established that PCBs pose the potential for adverse effects, the true effect of PCB exposure on Study Area populations is still unknown because of a number of uncertainties. These include quantifiable uncertainties about dietary exposure and about PCB dose-response, and quantifiable uncertainty about the level of effect associated with a population-level response. These uncertainties have not been fully examined in the BERA.

Reproductive success in spotted sandpiper, bald eagle, and osprey might also be reduced because of PCB exposure, as indicated by spotted sandpiper and bald eagle HQs ≥ 1 throughout the Study Area (max HQ = 12 for sandpiper and 3.9 for eagle) and by less widespread osprey HQs ≥ 1 (max HQ = 4.4). Overall, a greater degree of uncertainty is associated with PCB risk estimates for birds than for mammals because of uncertainty about exposure and uncertainty in the effects data. Uncertainty is higher for otter than for mink because otter-specific effects data are lacking.

Total 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) toxic equivalent (TEQ) exposure also poses ecologically significant risk of reduced reproductive success to populations of mink (with HQs up to 12). Total TEQ risk to birds and otter is low, considering the WOE for eagle and osprey, the more limited spatial extent of TRV exceedances for sandpiper, and the low magnitude of HQs for river otter. PCBs are responsible for the majority of total TEQ exposure, in that PCB TEQ HQs generally constitute the majority of the total TEQ HQs. For example, mink total TEQ HQs are ≥ 1 in 16 of 109 potential prey samples; of these samples, PCB TEQ HQs are ≥ 1 in 15 samples and total dioxin/furan TEQ HQs are ≥ 1 in only 4 samples. As is the case for PCBs, a greater degree of uncertainty is associated with total TEQ risk estimates for birds and otter than for mink because of uncertainties in both exposure and effects data for birds and uncertainty in effects data for otter.

Osprey egg data indicate that DDx compounds pose negligible risk to osprey and low to negligible risk of reduced reproductive success to individual bald eagles within limited portions of the Study Area. The only other wildlife receptor with a DDx HQ ≥ 1 is the spotted sandpiper. DDx compounds pose negligible risk to the spotted sandpiper population because the HQs are of low magnitude, span a limited spatial extent, and based on uncertainties in exposure and effects that likely cause overestimates of risk.

The spatial extent of copper HQ ≥1 in sandpiper encompasses a large portion of the Study Area; however, risk is negligible. Only one prey item (laboratory-exposed worms) had tissue concentrations associated with an HQ ≥ 1. Copper HQs based on a mixed-species diet are < 1. Additionally, the selected TRV was below the lowest bounded literature-reported NOAEL for birds.

Risk to wildlife from other COPCs that resulted in HQ ≥ 1 in the final step of the risk characterization were found unlikely to result in ecologically significant adverse effects on the receptor populations because the HQs are of low magnitude, span a limited spatial extent, and are based on uncertainties in exposure and effects that likely cause an overestimate of risk.

2.3.4 Amphibians

The amphibian assessment endpoints are survival, growth, and reproduction of amphibians. The assessment endpoints are based on protection and maintenance of populations and the communities in which they live, except for threatened or endangered species, which are to be protected at the organism level. For all COPCs with HQs ≥ 1, the risk to amphibian populations was assessed to be negligible. COPCs in surface water samples resulting in HQ ≥ 1 were found at concentrations below amphibian-specific thresholds or were collected during non-reproductive periods (when amphibians may not be present in the Study Area). For the TZW LOE, the great majority of samples result in HQs < 1, indicating limited spatial extent of exceedance. Although risk to amphibians from TZW is highly uncertain, it is likely to be negligible because significant exposure to Study Area TZW by this receptor group is unlikely.

2.3.5 Aquatic Plants

The aquatic plant assessment endpoints are survival, growth, and reproduction of aquatic plants. The assessment endpoints are based on protection and maintenance of populations and the communities in which they live, except for threatened or endangered species, which are to be protected at the organism level. For all COPCs with HQs ≥ 1, the risk to aquatic plant populations was assessed to be negligible. The same COPCs whose surface water HQ is ≥ 1 were found in the great majority of samples to have HQ < 1 and at concentrations generally below algae-specific thresholds. For the TZW LOE, the great majority of samples result in HQs < 1, indicating limited spatial extent of exceedance.

2.3.6 Potential Future Risks to the Benthic Community

Risk to the benthic community was assessed both for current conditions in the Study Area and estimated future conditions.[11] For the majority of erosional sediments (approximately 60%), there was no change of status in predicted risk to the benthic community (i.e., the sediment quality was similar at the erosional depth and the surface). This finding is not surprising because the erosional sediments are predicted to be primarily sands. Of the remaining erosional sediments, approximately 24% is predicted to be more contaminated in the future. The last 16% of the erosional area is predicted to be cleaner after the erosional event.

[11] The future condition assessment is based on the maximum bed change scenario presented in the draft final RI and a sample-by-sample evaluation of changes in status of predicted risk in the erosional areas based on comparison to site-specific SQVs.

3.0 RISK MANAGEMENT RECOMMENDATIONS

This section presents the LWG's ecological risk management recommendations to develop and evaluate remedial alternatives that are protective of ecological resources. Risk management recommendations are provided in three main parts:

- Section3.1 presents recommended contaminants of concern (COCs) for populations of fish and wildlife receptors.[12]
- Section 3.2 presents recommendations regarding contaminants present in TZW. TZW risk management recommendations are presented separately from those for other exposure media because the TZW LOE focuses on a spatially limited set of nine TZW sampling areas; the other exposure media (sediment, tissues, and surface water) were evaluated Study Area-wide. Furthermore, the TZW sampling areas were selected to capture information at locations with known or likely pathways for ongoing sources (discharge of upland contaminated groundwater), whereas the other exposure media were investigated because they represent complete exposure pathways to ecological receptors from contaminated sediment. Thus, both the nature and extent of risk as well as the alternatives for addressing them are unique for TZW.
- Section 3.3 presents risk management recommendations for protection of the benthic invertebrate community. As the BERA's benthic risk conclusions rely heavily on LOEs that do not identify specific COPCs (i.e., empirical measurements of sediment toxicity, predictions of sediment toxicity based on multivariate statistical models, and benthic community data from sediment profile imaging [SPI] imagery), this section recommends methodologies for delineating benthic areas of concern (AOCs) and for evaluating the degree to which remedial action alternatives protect the benthic community.
- Section 3.4 summarizes the risk management recommendations.

3.1 RECOMMENDATION OF COCS FOR STUDY AREA POPULATIONS OF FISH AND WILDLIFE RECEPTORS

In this section, the entire set of contaminants identified as posing potentially unacceptable risk to fish and wildlife receptors is evaluated. The purpose of the evaluation is to identify the COPCs for fish and wildlife receptors to use in the feasibility study (FS) to develop and evaluate remedial alternatives that are protective of ecological resources. This subset of COPCs constitutes the recommended COCs.

The assessment endpoints for most of the ecological receptors identified in EPA's Problem Formulation are for protection of the populations of fish, birds, mammals, and amphibians, and for protection of communities of benthic invertebrates and aquatic plants. The exceptions are that assessment endpoints for special status species

[12] Where secondary benthic LOEs support these recommendations for fish and wildlife receptors, they are identified.

identified in EPA's Problem Formulation (i.e., bald eagle, juvenile Chinook salmon, and Pacific lamprey ammocoetes) are for protection at the level of the organism.

The COC recommendations provided in this section are intended to address Study Area-wide risks to receptor populations. These recommendations are also intended to be protective of the aquatic plant community and receptors assessed at the organism level, except risk to Pacific lamprey ammocoetes from TZW exposure. Recommendations regarding risks from exposure to contaminants posing potentially unacceptable risk in TZW are presented in Section 3.2. Recommendations regarding identification of benthic risk areas and related protectiveness are provided in Section 3.3.

The remainder of Section 3.1 is presented in three main parts:

- Section 3.1.1 presents the rationale for COC recommendations.
- Section 3.1.2 applies that rationale to recommend COCs.
- Section 3.1.3 provides additional recommendations for the contaminants posing potentially unacceptable risk that are recommended as COCs. This includes recommendations about which receptors of concern should be considered along with the COCs to assess the protectiveness of potential remedies in the FS analysis of alternatives.

3.1.1 Rationale for COC Recommendations

COCs will be used to develop and evaluate remedial alternatives that are protective of ecological resources. The FS will also evaluate whether remedial alternatives for these COCs address the full list of contaminants posing potentially unacceptable risk.

The COC recommendations took into account one or more of the following factors:

- How often, where, and in which media risk thresholds were exceeded
- The ecological relevance (strengths and weaknesses) of the exposure estimates used to calculate HQs
- The toxicological effects associated with the TRV
- The magnitude of the exceedance
- Whether a relationship was found between COPC concentrations in co-located sediment and tissue concentrations (for small-home-range species)
- The relative strength and concordance among LOEs used to evaluate risks
- Comparison of Study Area concentrations with available background or upriver data

Some of these factors are strongly risk-based (e.g., the toxicological effects associated with the TRV, and the relative strength and concordance among LOEs), whereas others are more directly related to practical FS considerations (e.g., whether a relationship was found between COPC concentrations in co-located sediment and tissue concentrations for small-home-range species, and comparison with available background or upriver data).

3.1.2 COC Recommendations

Table 1 summarizes the contaminants posing potentially unacceptable risk in this BERA and whether they are recommended as COCs for fish and wildlife receptors. Contaminants posing potentially unacceptable risk based on the TZW LOE are discussed in Section 3.2. Areas and contaminants posing potentially unacceptable risk to the benthic community are discussed in Section 3.3; however, where benthic tissue-residue and surface water LOEs support the selection of COCs for protection of fish and wildlife, they are noted. Nineteen COPCs with at least one HQ $\geq$ 1 have been identified in this BERA for fish and wildlife receptors.[13,14] The set consists of seven metals, two butyltins, three PAHs, two phthalates, PCBs, dioxins/furans, two pesticides, and one VOC. The specific rationale for COC recommendations—based on the seven factors identified in Section 3.1.1—is provided below.

3.1.2.1 Recommended COCs

3.1.2.1.1 PCBs

PCBs is recommended as a COC because exposure poses a risk of ecologically significant adverse effects to mink and river otter populations. It also poses risk of ecologically significant adverse effects to spotted sandpiper, osprey, sculpin, and smallmouth bass populations and risk of adverse effects to bald eagles. The benthic tissue-residue LOE also supports the selection of PCBs as a COC. These additional risks are lower than the risk to mink and river otter populations. Further risk management recommendations regarding PCBs are provided in Section 3.1.3.

3.1.2.1.2 Dioxins/Furans

Total TEQ is recommended as a COC because exposure poses a risk of ecologically significant adverse effects to mink populations. Total TEQ also poses risk of adverse effects to river otter, spotted sandpiper, and osprey populations and to bald eagles. These latter risks are lower than the risk to the mink population. Further risk management recommendations regarding dioxins/furans are provided in Section 3.1.3.

[13] PCB TEQ and dioxin/furan TEQ are not included in this count because they are components of the total TEQ.
[14] Risk management recommendations for the benthic community assessment endpoints and the TZW LOE are handled separately and are not included in this COPC count.

3.1.2.2 COPCs Not Recommended as COCs

3.1.2.2.1 Inorganic Metals

None of the seven metals with HQ ≥ 1 is recommended as a COC for assessing potential remedy protectiveness of ecological receptors. The rationales for exclusion are as follows:

- Aluminum poses potentially unacceptable risk only for mink. For the following reasons, it is not recommended as a COC:
  - Aluminum exceeds the dietary TRV only based on sediment ingestion, no prey samples exceed the effects threshold.
  - TRV is based on exposure of mice to a highly soluble ionic form of aluminum with higher bioavailability than typically found in the diet or drinking water.
  - Study Area sediment and surface water concentrations are similar to background.
- Antimony poses potentially unacceptable risk based only on the tissue-residue LOE for smallmouth bass. For the following reasons, it is not recommended as a COC:
  - Low frequency of TRV exceedance (1 of 32 [3.1%] smallmouth bass samples)
  - Weakness of the exposure estimate (the single composite sample is an outlier for both antimony and lead, suggesting that a fish in the sample might have swallowed a fishing sinker)[15]
  - Weakness of the effects estimate (TRV is based on a single study with a generic acute-to-chronic ratio [ACR] applied)
  - Absence of relationship between concentrations in sediment and co-located tissue samples (Windward 2009)
- Discordance between the weaker tissue-residue LOE and the stronger surface water LOE (surface water TRV based on numerous exposure data and moderately sized Tier II effects dataset). Arsenic poses potentially unacceptable risk to benthic invertebrates based only on the tissue-residue LOE. It is not recommended as a COC for two reasons:
  - Low frequency of exceedance of the TRV (2 of 35 samples)
  - Low magnitude of the exceedance (maximum HQ = 1.5)

[15] Antimony can be mixed with lead as a hardener for lead-based products (ATSDR 1992). For example, one fish tackle supplier notes that fishing sinkers contain 94% lead and 6% antimony for hardness and color (Blue Ocean Tackle 2011).

- Cadmium poses potentially unacceptable risk based only on the dietary LOE for juvenile Chinook salmon and sculpin. For the following reasons, it is not recommended as a COC:
  - Low frequency of TRV exceedance in sculpin prey samples (9 of 111 [8.1%] prey samples, with maximum HQ = 2.2; and 1 of 1,348 [< 0.1%] sediment samples)
  - Weakness of the Chinook exposure estimate (juvenile Chinook were conservatively presumed to feed predominantly on benthic organisms; this feeding strategy is contrary to the literature, which shows they feed predominantly on pelagic organisms)
  - Uncertainty about the toxicological effects associated with the TRV (rockfish lowest-observed-adverse-effect level [LOAEL] setting the TRV is 2 to 3 orders of magnitude below the nine NOAELs from other studies, including four NOAELs and two LOAELs for salmonids)
  - Low magnitude of juvenile Chinook salmon dietary HQ (3.5 assuming mixed prey diet) when taking into account the likelihood that both exposure and effects are overestimated (per the two previous items)
  - Discordance of the dietary LOE with the surface water and tissue-residue LOEs (the cadmium ambient water quality criterion [AWQC] is based on a very large dataset so is the strongest LOE; the tissue-residue LOE is weak because fish sequester or otherwise bioregulate inorganic metals)
- Copper poses potentially unacceptable risk based on the fish tissue-residue, fish dietary, sandpiper dietary, and the benthic invertebrate tissue-residue LOEs. For the following reasons, copper is not recommended as a fish COC:
  - Weakness of the tissue-residue LOE for inorganic metals (fish can actively bioregulate copper tissue concentrations; invertebrates sequester copper and in the case of crayfish, copper forms the basis of their hemoglobin)
  - Irreproducible toxicological effects associated with the dietary TRV (selected LOAEL could not be replicated in subsequent tests with the same species)
  - Selected LOAEL is barely above range of nutritional requirements found in the literature for some fish species
  - Discordance of the tissue and dietary LOEs with the stronger water LOE (which is based on numerous exposure data and a very large AWQC dataset showing that fish are not among the most sensitive species; absence of HQ $\geq$1 via the water LOE is the strongest evidence for drawing risk conclusions)
  - Similarity of fish tissue concentrations in the Study Area and upriver

For the following reasons, copper is not recommended as a shorebird COC:

- Unlikely ecological significance of prey organism TRV exceedance (tissue-residue HQ ≥ 1 in only one prey item, laboratory-exposed worms; HQs < 1 for a mixed-species diet).
- The selected TRV is less than the lowest bounded literature-reported NOAEL for birds.
- Low magnitude of TRV exceedance (maximum HQ = 1.3) considering the likely overestimates of exposure and effects (per the two previous items)

For the following reasons, copper is not recommended as a benthic invertebrate COC:

- Low magnitude of TRV exceedance (maximum HQ = 2.6)
- Weakness of the tissue-residue LOE for inorganic metals (invertebrates sequester copper and in the case of crayfish, copper forms the basis of their hemoglobin)

• Lead poses potentially unacceptable risk based on the tissue-residue LOE for peamouth and smallmouth bass, and on the dietary LOE for osprey and mink. It is not recommended as a fish COC for the following reasons:

  - Low frequency of tissue TRV exceedance (2 of 32 [6.2%] smallmouth bass and 1 of 4 [25%] peamouth samples)
  - Weakness of the exposure estimate (smallmouth bass concentration yielding high HQ [280] is an outlier for both antimony and lead in the same sample, suggesting that a fish in the composite sample might have swallowed a fishing sinker)
  - Discordance of tissue-residue LOE with dietary and water LOEs (based on a very large dataset, the lead AWQC is the strongest LOE; the tissue-residue LOE is weak because fish generally can sequester or otherwise bioregulate inorganic metals; the dietary LOE is more likely to overpredict than underpredict risk)

  Lead is not recommended as a bird or mammal COC because the only sample yielding an HQ ≥ 1 is the same outlier smallmouth bass sample as identified for antimony above

• Zinc poses potentially unacceptable risk for fish (sculpin, bass, pikeminnow), amphibians, and aquatic plants based only on the surface water LOE. It poses a potentially unacceptable risk to benthic invertebrates based on the surface water and tissue-residue LOEs. It is not recommended as a COC for the following reasons:

  - Low frequency of surface water TRV exceedance for all receptors (1 of 167 samples [< 1%], with maximum HQ = 1.2)

- Discordance of the stronger surface water LOE with the weaker tissue-residue and dietary LOEs for fish (surface water toxicity data were sufficient to derive AWQC; tissue-residue LOE is weak because fish generally can sequester or otherwise bioregulate inorganic metals; the dietary LOE is relatively weak because the TRV is based on only two studies)
- The tissue-residue LOE for benthic invertebrates is a weak LOE

3.1.2.2.2 Organometals

- Mercury poses potentially unacceptable risk based on the dietary LOE for sculpin and bald eagle. It is not recommended as a fish COC because the dietary TRV was exceeded in only 1 of 1,345 sediment samples (< 0.001%) and in no tissue samples. Mercury is not recommended as an eagle COC for the following reasons:
  - Discordance between the dietary and tissue-residue LOEs
  - Possible overestimate of bald eagle exposure when using osprey exposure as a surrogate because of greater proportion of terrestrial prey in the bald eagle diet
  - Low HQ (maximum HQ = 1.7) given the discordant LOEs and possibility that exposure is overestimated (per the previous two items)
  - Higher concentrations in upriver fish tissue than in Study Area fish tissue
- Monobutyltin poses potentially unacceptable risk based on the surface water LOE. It is not recommended as a COC for three reasons:
  - Low frequency of surface water TRV exceedance (1 of 167 samples [< 1%])
  - Likely overestimate of toxicological effects associated with the TRV (which is based on the more toxic TBT)
  - Low magnitude of exceedance (HQ = 1.2) considering the likely overestimate of effects and limited spatial extent of HQ ≥ 1 (per the previous two items)
- TBT poses potentially unacceptable risk based on the dietary LOE for sculpin and tissue-residue LOE for benthic invertebrates. It is not recommended as a COC for fish for the following reasons:
  - Single dietary TRV exceedance (based on 1 lab worm sample of 81 prey samples [1.2%] and only when combined with sediment ingestion)
  - Low magnitude of exceedance (maximum HQ = 1.0)
  - Uncertainty about toxicological effects associated with the TRV (reproduction success was reduced at the TRV, but not dose-responsive)
  - Discordance of dietary LOE with the tissue-residue and water LOEs (TBT tissue residue is noted to be reliable predictor of toxicity and is the strongest LOE (Meador et al. 2002))

It is not recommended as a COC for benthic invertebrates because of the following:

- The TRV was exceeded in empirical bioaccumulation samples only at one location.
- While predicted tissue residues exceeded the TRV more frequently, the moderate strength of the regression was highly influenced by the one high value in the dataset. The predicted tissue residues are uncertain and not supported by empirical data.
- The TRV is uncertain due to the inclusion of imposex—the endpoint that defined the lower distribution of the species sensitivity distribution (SSD), which set the TRV

3.1.2.2.3 PAHs[16]

Benzo(a)anthracene, benzo(a)pyrene, and naphthalene pose potentially unacceptable risk to benthic invertebrates, fish, amphibians, and aquatic plants based on the surface water LOE. Benzo(a)pyrene poses potentially unacceptable risk to spotted sandpiper based on the dietary LOE. None of these three individual PAHs is recommended as a COC for assessing potential remedy protectiveness of ecological receptors.[17]

- Benzo(a)anthracene is not recommended as a COC for two reasons:
  - Low frequency of surface water TRV exceedance (2 of 245 samples [< 1%], both between RM 6.4 and RM 6.5[18]
  - Discordance of surface water LOE with dietary LOE for fish (benzo(a)anthracene did not screen in as a fish COPC by the dietary LOE)
- Benzo(a)pyrene is not recommended as a COC based on the surface water LOE for two reasons:
  - Low frequency of surface water TRV exceedance (3 of 122 [2.4%] near-bottom surface water samples, all from RM 6.4 to RM 6.5)[19]
  - Discordance of the surface water LOE with the dietary LOE for fish (benzo(a)pyrene did not screen in as a fish COPC by the dietary LOE)
- Benzo(a)pyrene is not recommended as a COC based on the bird dietary LOE for two reasons:

[16] Risk management recommendations regarding PAHs as they relate to risks from the TZW LOE and benthic AOCs are discussed separately in Sections 2.2.2 and2.2.3, respectively.
[17] In the TZW LOE, however, concordance of surface water and TZW exceedances at RM 6.4 to RM 6.5 supports identification of benzo(a)anthracene, benzo(a)pyrene and naphthalene as COCs for this location (see Section 1.2.2).
[18] In the TZW LOE, however, concordance of surface water and TZW exceedances at this sampling location support identification of benzo(a)anthracene as a COC for this location (see Section 1.2.2).
[19] In the TZW LOE, however, concordance of surface water and TZW exceedances at this sampling location support identification of benzo(a)pyrene as a COC for this location (see Section 1.2.2).

- Low frequency of dietary TRV exceedance for spotted sandpiper (1 of 27 [3.7%] lab worm samples assuming lab worm-only diet; all HQs < 1 for clam-only diet)
- Low magnitude of exceedance (maximum HQ = 1.6) considering potential overestimate of exposure by presuming lab worm-only diet

- Naphthalene is not recommended as a COC for two reasons:
  - Low frequency of surface water TRV exceedance (10 of 268 [3.7%] samples, all from west side of RM 6.4 to RM 6.5 during a single sampling event [the May 2005 non-LWG sampling event])[20]
  - Discordance of the surface water LOE with the dietary LOE for fish (naphthalene did not screen in as a fish COPC by the dietary LOE)

3.1.2.2.4 Phthalates

Neither of the two phthalates is recommended as a COC:

- Bis(2-ethylhexyl) phthalate (BEHP) poses potentially unacceptable risk based on the benthic invertebrate and fish tissue-residue and surface water LOEs. It is not recommended as a COC for several reasons:
  - Low frequency of surface water TRV exceedance (2 of 190 samples [1.1%])
  - Low frequency of fish tissue-residue TRV exceedance (1 of 38 sculpin samples [2.6%], 2 of 32 smallmouth bass samples [6.3%]) and low frequency of the benthic invertebrate tissue-residue TRV exceedance (1 of 35 clam samples or 3%)
  - Low magnitude of exceedance for fish tissue TRV (maximum HQ = 2.9) and for benthic invertebrate TRV (maximum HQ = 2.8)
  - Absence of toxicological effects associated with the tissue TRV (which is based on an unbounded NOAEL)
  - Absence of relationship between concentrations in co-located sediment and tissue samples
- Dibutyl phthalate poses potentially unacceptable risk based on the dietary LOE for spotted sandpiper. It is not recommended as a COC for several reasons:
  - Low frequency of dietary TRV exceedance (1 of 28 clam samples [3.6%], no worm samples)
  - Low magnitude of dietary TRV exceedance (maximum HQ = 1.4 for clam-only diet; maximum HQ < 1 for worm-only diet)

[20] In the TZW LOE, however, concordance of surface water and TZW exceedances at this sampling location support identification of naphthalene as a COC for this location (see Section 3.2).

- Absence of a relationship between concentrations in co-located sediment and tissue samples
- Higher sediment concentrations in background than in Study Area

3.1.2.2.5 Pesticides

None of the three organochlorine pesticides is recommended as a COC for assessing potential remedy protectiveness of ecological receptors:

- Aldrin poses potentially unacceptable risk based on the dietary LOE for spotted sandpiper. It is not recommended as a COC for two reasons:
  - Low frequency of dietary TRV exceedance (1 of 27 lab worm samples [3.7%])
  - Low magnitude of exceedance (maximum HQ = 1.4 based on the only lab worm sample that yields an HQ ≥ 1; HQ < 1 for clam-only and mixed diets)
- Total DDx poses potentially unacceptable risk based on the tissue-residue LOE for sculpin and benthic invertebrates; the dietary LOE for spotted sandpiper; the egg LOE for bald eagle; and the surface water LOE for the benthic community, sculpin, amphibians, and aquatic plants. The rationale for exclusion from the list of recommended COCs varies with LOE[21] DDx is not recommended as a COC for the following reasons:
  - Low frequency of TRV exceedance (1 of 170 samples [< 1%]) in surface water based on N-qualified data, indicating interference from another analyte
  - Low frequency of exceedance in empirical benthic tissue residue (2 of 35 worm samples or 6%)
  - Low frequency of exceedance in predicted benthic tissue residues (up to 15 samples of 1,128 or 1.3%) and approximately half of which are based on N-qualified data
  - Low frequency of TRV exceedance (2 of 27 lab worm samples [7.4%]) used in the dietary LOE for sandpiper
  - Low magnitude of exceedance of TRV for sandpiper diet (maximum HQ = 1.4 assuming lab worm-only diet; HQ < 1 for all clam-only and mixed diets)
  - Questionable relevance of estimated exposure for the bird egg LOE for bald eagle (there is significant uncertainty about the source of DDx residues in the osprey eggs collected from the Study Area because the adults overwinter in Mexico and Central America, nesting and laying eggs shortly after returning to the lower Willamette (Henny et al. 2004)

[21] Total DDx and 4,4′-DDT are recommended as TZW COCs in the TZW sampling area at ~RM 7.4W (see Section3.2).

- Potential risk of adverse effects on bald eagles is present because NOAEL HQs are ≥ 1 in eggs from two of five exposure areas;because both were below the LOAEL, there is no empirical evidence of potential risk.
- All egg total DDx concentrations were below the recommended effects threshold reported in Elliott and Harris (2001\2002) based on a comprehensive review of the available bald eagle toxicological effects data
- Absence of relationship between concentrations in osprey egg samples and nearby sediment (NOAEL HQ ≥ 1 in eggs from two of five exposure areas, but NOAEL HQ < 1 in eggs from where sediment DDx concentrations were highest)
- Discordance of LOEs (mixed species dietary NOAEL HQs < 1 in all exposure areas)

- 4,4′- dichlorodiphenyldichloroethane (4,4′-DDD) poses potentially unacceptable risk based on the tissue-residue LOE for benthic invertebrates. This contaminant is not recommended as a COC for the following reasons:
  - Low frequency of TRV exceedance (1 of 35 samples or < 3%)
  - Low magnitude of the exceedance (HQ = 1.2)

3.1.2.2.6 VOCs

Two VOCs (ethylbenzene and trichloroethene) measured in surface water exceeded their respective TRVs; however, neither is recommended as a COC based on the following rationale:

- Low frequency of exceedance; TRV exceeded in 1 of 23(4%) samples collected from ~ RM 6.5 (west bank) during one sampling event
- Low magnitude of exceedance of the TRV for ethylbenzene (HQ = 1.6)

3.1.3 Risk Management Recommendations for Recommended COCs

Based on the information presented in Section 3.1.2, PCBs and total TEQ pose the primary risks to fish and wildlife. The remainder of this section provides additional risk management recommendations for these recommended COCs:

- Section 3.1.3.1 recommends the use of mink to evaluate PCB and total TEQ remedies.
- Section 3.1.3.2 examines relationship between PCB and TEQ risk.
- Section 3.1.3.3 discusses potential problems with the use of the bird egg LOE as an evaluation tool for potential remedies.

3.1.3.1 Receptors of Concern for Purposes of Assessing the Protectiveness of Potential Remedies in the FS Analysis of Alternatives.

PCBs are recommended as a COC because exposure poses a risk of ecologically significant adverse effects to mink and river otter populations. PCBs also poses lower risk of ecologically significant adverse effects to benthic invertebrates, spotted sandpiper, osprey, sculpin, and smallmouth bass populations and to bald eagles. Total TEQ is recommended as a COC because exposure poses a risk of ecologically significant adverse effects to mink populations. Total TEQ also poses lower risk of adverse effects to river otter, spotted sandpiper, and osprey populations and to bald eagles.

For the dietary LOE, HQs are a function of food and sediment ingestion rates relative to the organism's body weight, the COPC concentrations in prey and sediment, and the TRV. Of the receptors at risk from PCBs and total TEQ via the dietary LOE, mink has the lowest TRVs. The bird PCB LOAEL TRV is higher than that of mink by a factor of 16 and the bird total TEQ LOAEL TRV is higher than that of mink by a factor of 64, indicating that risk to mink occurs at lower dietary doses.

Given the same sediment and prey data, dietary risk estimates for mink will always be higher and more widespread than those for the other receptors. Food and sediment ingestion rates as a function of body weight are higher for mink than for otter; and they are higher for birds than for mink (by a factor ranging from 1.3 for osprey to 7 for spotted sandpiper). However, the difference in TRVs (for both PCBs and total TEQ) more than offsets the difference in ingestion rates. Although a mink population is not known to be present in the Study Area, mink are assumed to forage in all areas of the Study Area and to prey on small- and large-home-range fish. Analysis of remedial alternatives for mink will thus be protective of other receptors in the Study Area potentially affected by PCBs and dioxins.

Predicted mink risk is based on species-specific effects data, making mink risk predictions a relatively strong basis for risk management decisions. This is not the case for the other receptors (predicted risks are not based on species-specific effects data), whose conclusions therefore provide a less certain basis for risk management recommendations. Because the available data suggest that mink are quite sensitive to PCBs and dioxins/furans, and probably more so than the other receptors at risk, the mink population should be the receptor of concern when assessing ecological risk reduction for the remedial alternatives (for PCBs and total TEQ).

Because protection of other receptors by mink is contingent on the habitat use, prey, and home-range assumptions used for the BERA, any alteration of these assumptions for analysis of uncertainties in the FS should be examined to ensure that protection of all receptors at risk from PCBs and TEQ are still protected under alternate assumptions for mink.

Because the relationship between sediment contamination and bird egg tissue concentrations is highly uncertain, the tissue-residue LOE has limited utility as a tool for assessing the protectiveness of potential remedies in the FS analysis of alternatives. This is discussed further in Section 3.1.3.3.

3.1.3.2 Relationship Between PCB and TEQ Risk

Total TEQ is the sum of multiple PCB and dioxin/furan congeners, each weighted by their toxicity relative to that of the most toxic congener (2,3,7,8-TCDD). TEQ concentrations for birds and mammals were calculated as the sum of individual PCB and dioxin/furan congener concentrations weighted by their toxic equivalency factors (TEFs). The PCB TEQ is the TEF-weighted sum of only the dioxin-like PCB congener concentrations, the total dioxin/furan TEQ is the TEF-weighted sum of only the dioxin/furan congener concentrations, and total TEQ is the sum of the PCB TEQ and the total dioxin/furan TEQ. TEF values for a given congener generally fall within a range of about an order of magnitude for mammals (Sanderson and Van den Berg 1999); TEFs for birds are more uncertain (Van den Berg et al. 1998). Because of this uncertainty, TEQ risks may be over- or underestimated.

As with PCBs, mink is the receptor most sensitive to dioxins/furans and subject to the greatest spatial extent of TEQ risk in the Study Area. PCBs are responsible for the majority of total TEQ risk, in that PCB TEQ HQs generally constitute the majority of the total TEQ HQs. For example, of the 15 (out of 109) potential prey samples with mink total TEQ HQ ≥ 1, 7 exceed the TRV for PCB TEQ but only 4 exceed the TRV for total dioxin/furan TEQ. No individual samples result in an exceedance of both the PCB TEQ TRV and the dioxin/furan TEQ.

Because total TEQ risk is largely driven by PCB, and redundant with PCB risk (with the four exceptions noted above), and because adverse effects in mink are better correlated with PCB exposures than with TEQ exposures (Fuchsman et al. 2007), the FS analysis of alternatives should focus primarily, but not exclusively, on evaluating whether remedies protect the mink population from risk due to exposure to PCBs.

3.1.3.3 Bird Egg LOE and the FS

PCBs and total TEQ pose low risk to birds based on the tissue-residue LOE. It is recommended that the bird egg LOE not be used to develop and evaluate remedial alternatives in the FS. Risk to osprey and bald eagle based on the egg LOE cannot be directly compared with dietary risks. Egg tissue concentrations might reflect exposure to contaminated prey from the Study Area. Alternatively, inasmuch as osprey lay eggs shortly after returning to the Study Area from overwintering in Mexico and Central America, the egg residues might reflect exposure to contaminants outside of the Study Area. Furthermore, the bioaccumulation relationship from prey to egg is not well-characterized, rendering predictions based on this relationship highly uncertain.

A statistical evaluation was conducted to determine if a relationship between fish tissue and bird egg tissue concentrations in the Study Area could be expressed using biomagnification regressions (BMRs). A BMR expresses the relationship between fish prey and bird egg tissue concentrations based on co-located data rather than based on an average ratio. BMRs were calculated based on the method by Burkhard (2006) using co-located (within 1 mile) composite fish tissue and egg concentrations from seven locations throughout the Willamette River (Henny et al. 2003; 2008). Several possible linear tissue-sediment models were screened. No significant relationship (i.e., no BMR) could be found for any bird egg COPC based on the criteria of a significantly positive slope at a $p = 0.05$ and an $r^2 > 0.030$, except total TEQ ($r^2 = 0.52$). For total TEQ, application of the BMR to the Study Area requires extrapolation outside of the dataset, thus rendering the relationship uncertain. The implication is that the available dataset is insufficient to estimate a reliable BMR.

Because mink is the receptor most sensitive to PCBs and dioxins/furans, it is recommended that from an ecological risk management perspective, FS analyses should focus primarily on the mink dietary risk reduction associated with the remedial alternatives.

3.2 TZW RISK MANAGEMENT RECOMMENDATIONS

The TZW LOE was used to assess risks to benthic invertebrate, benthic fish (i.e., sculpin and lamprey ammocoetes), aquatic plant, and amphibian populations and communities. Pacific lamprey are identified in EPA's Problem Formulation as a "species of special concern" with direction to assess risk at the organism level. Measured TZW concentrations exceed water TRVs in all of the TZW sampling areas; by EPA's direction individual lamprey ammocoetes are exposed to potentially unacceptable risk. The degree to which TZW poses potentially unacceptable risk to individual lamprey ammocoetes is uncertain. Lamprey ammocoete toxicity testing has demonstrated their relative insensitivity to toxicants across six modes of action (Andersen et al. 2010). It is probable that the BERA overestimates both lamprey ammocoete exposure and effects, to an unquantified degree.

The TZW samples evaluated in this assessment were collected primarily during a 2005 sampling effort focused offshore of nine[22] upland sites with known or likely pathways for discharge of upland contaminated groundwater. The primary objective of the RI groundwater pathway assessment was to evaluate whether transport pathways from upland contaminated groundwater plumes to the river were complete. Therefore, TZW target analyte lists varied from site to site and were derived primarily based on the COIs in the upland contaminated groundwater plumes. Consequently, not all COIs in sediments were analyzed in TZW samples. As described in Sections 4.4.3.1 and 6.1.5.2 of the RI Report, there also might be other contaminated

[22] The area offshore of the Arkema site was divided into two areas (the acid plant area and the chlorate plant area).

groundwater plumes in the Study Area discharging into river sediments where TZW samples have not been collected.

TZW sampling focused on sites with groundwater pathways that were a potential concern. Where these groundwater pathways are confirmed to be a concern, they will be addressed through source control. Source controls should be in place prior to implementation of sediment remedies, particularly those associated with upland sources (EPA 2002, 2005) in order to prevent recontamination. These source control actions will reduce contaminant flux to the river and accelerate recovery. Source controls will reduce baseline risk by intercepting ongoing contaminant migration. While the residual contaminated groundwater plumes may remain near the mudline, they will attenuate over time. Because source controls should precede the sediment remedy, the magnitude of potential risk identified in the BERA should be diminished when the sediment remedy is implemented.

The TZW LOE was evaluated by comparing TZW COPC concentrations in individual samples to water effect thresholds. EPA directed the LWG to assume that benthic organisms would be exposed to undiluted shallow (0 to 38 cm) TZW, an assumption that the LWG found to be highly conservative. As discussed in Section 6.6.3.3 of the BERA (Windward 2011), actual TZW exposure is probably much lower because of feeding habits, burrowing behavior, avoidance of low oxygen levels at the TZW sample depths, and low food content in sediments at the TZW sample depths.

It is recommended that only those TZW COPCs with HQ ≥ 100 be considered as COCs to develop and evaluate remedial alternatives that are protective of ecological resources.[23] This recommendation is based on two factors. First, by definition any contaminant with HQ ≥ 1 poses potentially unacceptable risk, but the evidence presented in Section 6.6.3.3 of the BERA (Windward 2011) strongly supports the position that the potential for unacceptable risk at HQs < 10 is very small. Therefore, a factor of 10 was applied to account for the evidence that benthic receptors are not directly exposed to undiluted TZW. Second, EPA guidance (EPA 2005) states that remedies should be evaluated under the assumption that sources of COPCs to the groundwater plume have been controlled. The effect of source control should be to reduce the potential flux of groundwater COPCs into the shallow transition zone prior to sediment remediation. An additional factor of 10 was applied to account for the control of COPC sources.

Almost all metals measured in TZW are common crustal elements. Barium, iron, and manganese are among the most common metals associated with sediments. These same metals are also associated with the highest HQs in the risk characterization, but there is substantial uncertainty that their source is ubiquitously anthropogenic. It is

[23] There is uncertainty associated with 4,4′-DDT and total DDx as COCs because HQs based on filtered samples are less than 100. This suggests that the risk from DDx compounds in TZW may be lower than indicated by the maximum concentrations in unfiltered samples due to lower bioavailability of the particulate bound fraction of the contaminant.

recommended that TZW concentrations of these metals not be used to assess remedy effectiveness.

Given the foregoing, TZW COC recommendations for each site are provided in Table 2.

Potential remedies should be evaluated in the FS for the degree to which they protect benthic invertebrate communities and individual Pacific lamprey ammocoetes from risk due to contaminated groundwater discharge, assuming that groundwater source control measures have been implemented.

3.3 BENTHIC RISK MANAGEMENT RECOMMENDATIONS

The primary LOE for identifying benthic community risks is based on sediment toxicity (both measured and predicted based on multivariate statistical models [floating percentile model (FPM) and logistic regression model (LRM)]); however, the risk assessment methodologies are designed to address chemical mixtures. The results are correlative and do not conclusively identify contaminants causing toxicity.[24] Contaminants whose sediment concentrations, when considered as a group (i.e., in aggregate), appear to help explain the observed toxicity based on the FPM and LRM are presented in Table 3.[25]

Because the primary benthic LOE (bioassay results) does not identify the cause of the empirical toxicity (i.e., specific COPCs or other factors), the risk management recommendations focus on two other questions:

1. Where were potentially unacceptable benthic community risks occurring in the Study Area at the time of the BERA data collection?
2. What tools from the BERA can be used in the FS analysis of alternatives to assess the effectiveness of potential remedies on protecting the benthic community?

The remainder of this section is arranged around these two questions. Section3.3.1 outlines the guidelines EPA provided about how to answer them. Section 3.3.2 answers the first question by presenting recommended benthic AOCs. Section 3.3.3 answers the second question by recommending tools by which to assess the effect of potential remedies on the benthic community in the FS analysis of alternatives.

[24] Risk conclusions based on the secondary benthic LOEs—tissue residue, surface water, and TZW—can identify COCs and are noted in Sections 3.1 and 3.2, where these LOEs support the identification of COCs.
[25] The contaminant list is a combination of SQVs derived using the FPM and the LRM. Each SQV has a different reporting basis depending on the normalization selected for the model. All FPM SQVs are dry-weight normalized. LRM SQVs used a number of different normalizations including dry-weight, organic carbon, percent fines and combinations of normalizations.

3.3.1 EPA Guidelines for Evaluating Benthic Risk in the Feasibility Study

The LWG and EPA have been working on benthic risk management recommendations since early 2010, following guidelines EPA in an April 21, 2010 letter (EPA 2010). The guidelines provide direction for evaluating benthic risk in the draft FS. Specifically, EPA described its primary goals for the FS analysis of alternatives for benthic assessment endpoints:

- Define areas that pose unacceptable risk to the benthic community
- Define the areas and volume of contamination that may pose risk to the benthic community
- Evaluate remedial action alternatives and effectiveness (did it meet the remedial action objectives [RAOs])

The letter also provided guidelines for evaluating remedy effectiveness:

- All benthic sediment quality guidelines (SQGs) in the March 24, 2010 list will be included in the analysis. If specific SQGs are found to be inconsistent with other LOEs listed below, EPA will review the analysis and determine whether these should be included in the draft FS.[26]
- Sediment toxicity bioassays will form the primary LOE for this analysis. The sediment toxicity LOE will include level 2 (moderate) and level 3 (severe) effects for all endpoints (chironomus [sic] biomass and mortality and hyalella [sic] biomass and mortality).
- The analysis will consider the number and degree of exceedance of SQGs.
- The analysis will consider other LOEs such as TZW compared to AWQC for the protection of aquatic life and benthic tissue TRVs.
- The analysis will consider the presence/absence of nearby sources and examine benthic community structure (e.g., via SPI and related information).
- The analysis will consider data quality and data density issues for the SQGs.

The LWG's implementation of these guidelines is known by EPA and the LWG as the "comprehensive benthic approach." Developed by the LWG after receiving the EPA's April 21, 2010, directives and guidelines (EPA 2010), the comprehensive benthic approach was first presented informally to EPA (Eric Blischke and Burt Shephard) by the LWG (John Toll and Jim McKenna) on July 20, 2010, to elicit early feedback. It was formally presented to EPA during the September 29, 2010, LWG Small Technical Group Benthic Toxicity Areas of Potential Concern (AOPCs) Meeting with EPA. Item 11 in Attachment B to the LWG's January 12, 2011, letter to

[26] The SQVs have subsequently been revised based on additional modeling and negotiations between the LWG and EPA, as documented in item 11 of Attachment B to a January 12, 2011, LWG letter to EPA (LWG 2011a), the attachment to a February 25, 2011, RI/FS schedule letter from EPA to the LWG (Humphrey 2011), and the LWG's March 9, 2011, draft response (LWG 2011b) to EPA's February 25, 2011, letter.

EPA (LWG 2011a), and the attachment to EPA's February 25, 2011, response letter to the LWG (Humphrey 2011) document the decision to proceed with an updated version of the comprehensive benthic approach.

3.3.2 Recommended Benthic Areas of Concern for FS Evaluation

Recommended benthic AOCs, based on the LWG's application of the comprehensive benthic approach upon completion of the draft final BERA, are shown on Maps 1a and 1b. Sediment toxicity bioassays form the primary LOE for the comprehensive benthic approach used to delineate the recommended benthic AOCs, as per the EPA April 21, 2010, guidelines (EPA 2010). Predicted toxicity (based on multiple sets of SQVs) and tissue residues (both empirical and predicted) provide secondary LOEs to identify benthic risk areas. TZW and surface water were used as supporting LOEs.

SPI data were not used in the development of AOCs because the sampling program was not designed to link SPI image locations with toxicity sampling locations and in turn allow an assessment of the relationship between benthic community successional stage and contaminant effects. Details of the approach used to identify recommended benthic AOCs are as follows:

- Locations with empirical bioassay results indicating significant toxicity were identified.
  - One toxicity endpoint (*Chironomus* biomass or growth, *Hyalella* biomass or growth) exceeding an L3 threshold or two endpoints exceeding an L2 endpoint were considered significant toxicity.
- Locations where significant sediment toxicity is predicted based on sediment chemistry exceeding a mean quotient (MQ) of 0.7 or a pMax of 0.59 were identified.
  - Sampling locations where both the MQ and the pMax thresholds were exceeded were considered toxic.
  - Sampling locations where neither the MQ or pMax threshold was exceeded were considered non-toxic.
  - Sampling locations where the models disagreed (i.e., either the MQ or the pMax threshold was exceeded, but not both) were considered uncertain.
- Locations where empirical tissue residues or, in the absence of empirical tissue residue data, predicted tissue residues exceeded their TRVs were identified.
  - The evidence of risk provided by measured or predicted exceedance of metals TRVs was considered weak because of species-specific differences in metals sequestration or other bioregulation.

  - The evidence of risk provided by predicted exceedance of the TBT TRV was considered weak because of high uncertainty in the TBT bioaccumulation model.
- TZW exceedance areas with HQs>100 were delineated.
- All LOEs were overlaid on a map.
  - Areas where two or more adjacent empirical bioassay sampling locations indicate significant toxicity were identified as benthic AOCs.
  - Areas where risks were identified at two or more adjacent sampling locations based on chemistry LOEs (predicted toxicity, empirical or predicted bioaccumulation) or a combination of bioassay and chemistry LOEs were identified as benthic AOCs.
  - TZW exceedance areas were identified as benthic AOCs.
- Boundaries of the benthic AOCs split the distance between sampling locations exceeding criteria and surrounding clean sampling locations except where:
  - Other physical features were present (e.g., pier, channel edge, property boundary), in which case the boundary was drawn at the physical features.
  - The nearest sampling sampling location was at a distance greater than 200 feet, in which case the boundary was drawn at a subjective distance less than halfway to nearest sampling location.

3.3.3 Benthic Assessment Tools for the FS Analysis of Alternatives

Bioassays cannot form the primary LOE for the FS analysis of alternatives, because the analysis is of potential future conditions. Therefore, the sediment chemistry LOE, as applied in the comprehensive benthic approach, will have to be used to judge protectiveness of potential remedies. The comprehensive benthic approach uses concordance between an MQ based on the site-specific SQVs and the predicted pMax to identify benthic risk areas. EPA selected the MQ threshold of 0.7 and the pMax threshold of 0.59 that the LWG used in defining benthic AOCs. These same thresholds should be used to evaluate the protectiveness of potential remedies. The analysis of alternatives should also consider whether and how much natural recovery would occur prior to implementing active remedies. Per EPA guidance (EPA 2002, 2005), the analysis should presume that source control measures will be in place.

3.4 SUMMARY OF ECOLOGICAL RISK MANAGEMENT RECOMMENDATIONS

The following are recommended as receptor-COC pairs of concern for further consideration in the FS:

- For non-benthic invertebrate receptors, PCBs and total TEQ are the recommended COCs for assessing risk. Mink is the recommended receptor of concern. Most of the contaminants posing potentially unacceptable risk were not recommended as COCs for the non-benthic receptors based on risk characterization considerations (magnitude, spatial extent, and ecological significance of HQs ≥ 1). This list includes all the metals, butyltin, phthalate, pesticide, and VOC COPCs.
- For aquatic receptors exposed via TZW, 4,4′-DDT, total DDx,[27] chlorobenzene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and trichloroethene are the recommended COCs. These recommendations presume that groundwater source control measures will be implemented prior to sediment remedies. The Oregon Department of Environmental Quality (ODEQ) is working with upland property owners to implement contaminated groundwater source control measures prior to sediment remedies.
- For benthic receptors, recommended benthic AOCs were mapped by applying the comprehensive benthic approach based on EPA's April 21, 2010 guidelines for assessing benthic risk in the FS (EPA 2010). They are presented in Map 2. The FS analysis of alternatives will have to rely on the predicted toxicity metrics to evaluate potential remedies and should take into account sediment quality changes that will take place before active implementation of remedies.

[27] There is uncertainty associated with 4,4′-DDT and total DDx as COCs because HQs based on filtered samples are less than 100. This suggests that the risk from DDx compounds in TZW may be lower than indicated by the maximum concentrations in unfiltered samples because of the lower bioavailability of the particulate-bound fraction of the contaminant.

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Table 1. COC Recommendations for All Receptor Group-LOE Pairs with an HQ ≥ 1

COPC	Receptor Group - LOE Pairs Resulting in HQ ≥ 1
Contaminants Recommended as COCs	
PCBs	
Total PCBs	Benthic invertebrate – tissue residue (clam, worm)
	Fish – tissue-residue (sucker, sculpin, bass, pikeminnow)
	Mammal – diet (mink, river otter)
	Bird – diet (sandpiper, osprey, bald eagle, merganser)
	Bird – tissue-residue (osprey, bald eagle)
Dioxins/Furans	
Total TEQ[a]	Mammal – diet (mink, river otter)
	Bird – diet (sandpiper)
	Bird – tissue residue (osprey, bald eagle)
Contaminants not Recommended as COCs	
Inorganic Metals	
Aluminum	Mammal – diet (mink)
Antimony	Fish – tissue residue (bass)
Arsenic	Benthic invertebrate – tissue residue (worm)
Cadmium	Fish – diet (sculpin, Chinook)
Copper	Benthic invertebrate – tissue residue (clam, crayfish, worm)
	Fish – diet (sucker, sturgeon, Chinook, peamouth, sculpin, pikeminnow)
	Fish – tissue-residue (sculpin, Chinook, lamprey, pikeminnow)
	Birds – diet (sandpiper)
Lead	Fish – tissue-residue (peamouth, bass)
	Birds – diet (osprey)
	Mammals – diet (mink)
Zinc	Benthic invertebrates – surface water, benthic invertebrate tissue residue (clam, mussel, worm)
	Fish – surface water (sculpin, bass, pikeminnow)

Table 1. COC Recommendations for All Receptor Group-LOE Pairs with an HQ ≥ 1

COPC	Receptor Group - LOE Pairs Resulting in HQ ≥ 1
	Amphibians – surface water
	Aquatic plants – surface water
Organometals	
Mercury	Fish – diet (sculpin)
Monobutyltin	Benthic invertebrates – surface water
	Fish – surface water (sculpin, bass, pikeminnow)
	Birds – diet (bald eagle)
TBT	Benthic invertebrate (clam and worm tissue residue)
	Fish – diet (sculpin)
PAHs	
Benzo(a)anthracene	Benthic invertebrates – surface water
	Fish – surface water (sculpin, bass, pikeminnow)
	Amphibians – surface water
	Aquatic plants – surface water
Benzo(a)pyrene	Benthic invertebrates – surface water
	Fish – surface water (sculpin, bass, pikeminnow)
	Birds – diet (sandpiper)
	Amphibians – surface water r
	Aquatic plants – surface water
Naphthalene	Benthic invertebrates – surface water
	Fish – surface water (sculpin, bass, pikeminnow)
	Amphibians – surface water
	Aquatic plants – surface water
Phthalates	
BEHP	Benthic invertebrates – surface water, tissue residue (worms)
	Fish – tissue residue (sculpin, bass,)
	Fish – surface water (sculpin, bass, pikeminnow)
	Amphibians – surface water
	Aquatic plants – surface water
Dibutylphthalate	Birds – diet (sandpiper)

Table 1. COC Recommendations for All Receptor Group-LOE Pairs with an HQ ≥ 1

COPC	Receptor Group - LOE Pairs Resulting in HQ ≥ 1
Pesticides	
Aldrin	Birds – diet (sandpiper)
Total DDx[b]	Benthic invertebrates – surface water, tissue residue (clam, worm)
	Fish –tissue residue (sculpin)
	Fish – surface water (sculpin)
	Birds – diet (sandpiper)
	Birds – tissue residue (bald eagle)
	Amphibians – surface water
	Aquatic plants – surface water
4,4′-DDD	Benthic invertebrate – tissue residue (worms)
VOCs	
Ethylbenzene	Benthic invertebrates – surface water
Trichloroethene	Benthic invertebrates – surface water
	Fish – surface water (sculpin)

Notes:

a Total TEQ includes risk estimates for PCB TEQ and total dioxin/furan TEQ.

b Total DDx includes risk estimates for the additional DDx components that were also evaluated independently (sum DDE, 4,4′-DDE, and 4,4′-DDT). Risk estimates for the surface water LOE are based on the alternative 4,4′-DDT TRVs for protection of directly exposed aquatic organisms, rather than the AWQC-based TRV. The alternative TRV is considered more appropriate for evaluating direct exposure of aquatic organisms because the AWQC is based on protection of dietary risks to birds.

AWQC – ambient water quality criterion
BEHP – bis(2-ethylhexyl) phthalate
COC – contaminant of concern
COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HQ – hazard quotient
LOE – line of evidence
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TBT – tributyltin
TEQ – toxic equivalent
total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
TRV – toxicity reference value
VOC – volatile organic compound

Table 2. COC Recommendations for COPCs with HQs ≥ 100 at TZW Sampling Areas

	Maximum HQ ≥ 100									
		Arkema								
COPC	ARCO	Acid Plant	Chlorate Plant	Exxon Mobil	Gasco	Gunderson	Kinder Morgan	Rhône-Poulenc	Siltronic	Willbridge
Contaminants Recommended as TZW COCs										
Benzo(a)anthracene									1,200	
Benzo(a)pyrene					210				2,700	
Naphthalene					260				1,100	
4,4′-DDT		160[a]								
Total DDx		280[a]								
Chlorobenzene		190								
cis-1,2-Dichloro-ethene									110	
Trichloroethene									1,900	
Cyanide					4,400				130	
Carbon disulfide					870					
Contaminants Not Recommended as TZW COCs										
Barium (total)		610	1,100					170		
Iron (total)		110	250	110	130				180	120
Manganese (total)			550	150	130			130		110
Gasoline-range aliphatic hydro-carbons C10-C12[b]					540				150	

Notes:

a Maximum HQs are based on unfiltered samples. Maximum HQs for filtered samples would be 2.8 for 4,4′-DDT (however, this contaminant was never detected) and 14.5 for total DDx.

120

b Petroleum hydrocarbons may contribute to risks to ecological receptors; however, petroleum is not considered a CERCLA contaminant.

CERCLA –Comprehensive Environmental Response, Compensation, and Liability Act
COC – contaminant of concern
COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HQ – hazard quotient
total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)

Table 3. Contaminants Potentially Contributing to Benthic Risk Based on Predicted Sediment Toxicity LOE

Contaminant	
Metals	
Cadmium	Lead
Chromium[b]	Mercury[b]
Copper	Silver
PAHs	
2-Methylnaphthalene	Dibenzo(a,h)anthracene
Acenaphthene	Fluoranthene
Acenaphthylene	Fluorene
Anthracene	Indeno(1,2,3-cd)pyrene
Benzo(a)anthracene	Phenanthrene
Benzo(b)fluoranthene	Pyrene
Benzo(b+k)fluoranthene	Total HPAHs
Benzo(g,h,i)perylene	Total LPAHs[b]
Benzo(k)fluoranthene	Total PAHs
Chrysene	
Phthalates	
Dibutyl phthalate	
SVOCs	
Benzyl alcohol	Dibenzofuran[b]
1,2-Dichlorobenzene	Carbazole[b]
Phenols	
4-Methylphenol[a]	Phenol
PCBs	
Total PCBs[b]	
Pesticides	
2,4′-DDD	beta-HCH
4,4′-DDD	delta-HCH[b]
4,4′-DDE	Dieldrin
4,4′-DDT	Endrin
Sum DDD[b]	Endrin ketone
Sum DDE	cis-Chlordane

Table 3. Contaminants Potentially Contributing to Benthic Risk Based on Predicted Sediment Toxicity LOE

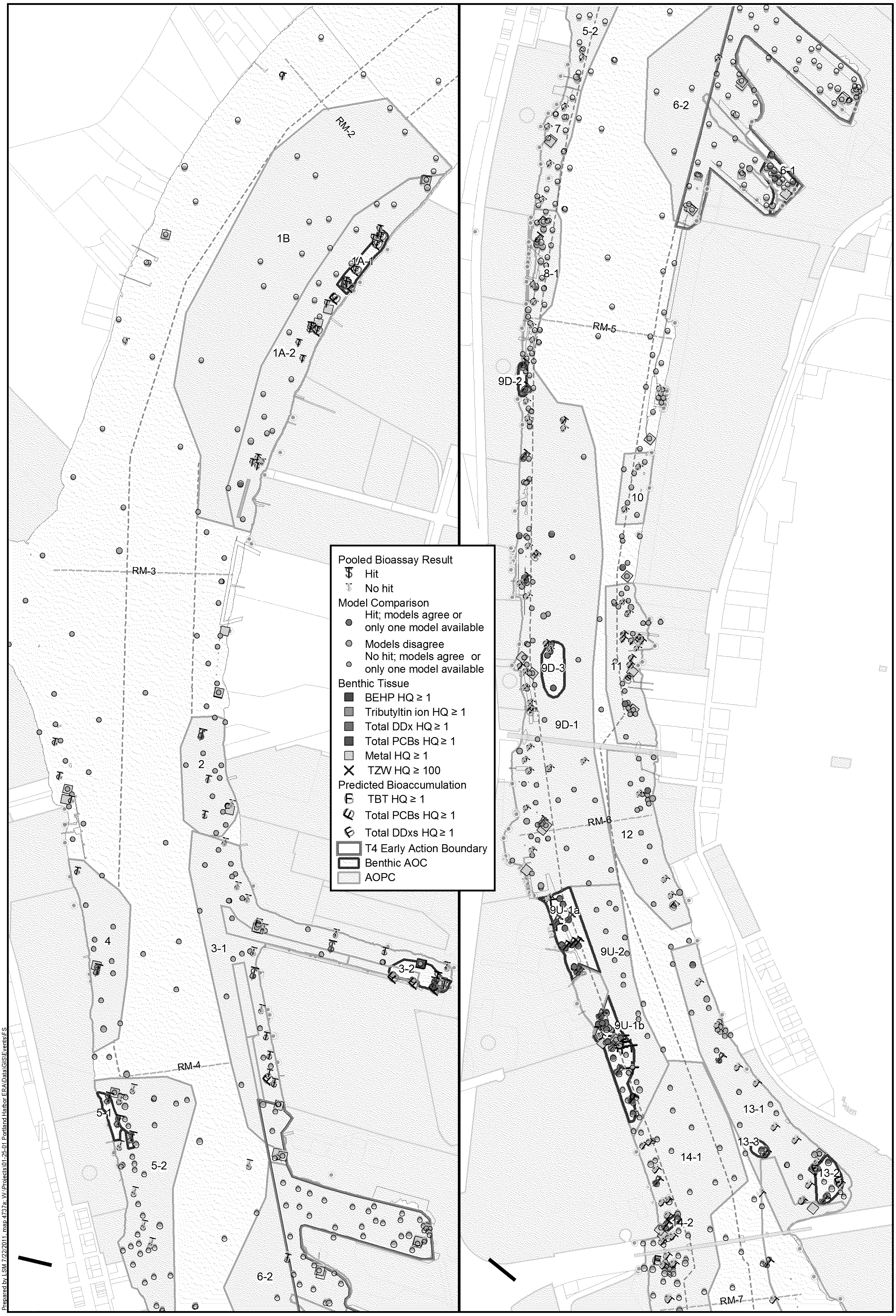
Contaminant	
Sum DDT	Total endosulfan[b]
Total DDx	
Petroleum Hydrocarbons	
Diesel-range hydrocarbons	

Notes:

a – all SQVs derived from the FPM are less than the apparent effect threshold and therefore may contribute to false predictions of toxicity.

b – FPM SQVs based on one or two endpoints are less than the apparent effect threshold and may contribute to false predictions of toxicity

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
FPM – floating percentile model
HCH – hexachlorocyclohexane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LOE – line of evidence
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
total DDx – sum of all six DDT isomers (2,4′-DDD; 4,4′-DDD; 2,4′-DDE; 4,4′-DDE; 2,4′-DDT; and 4,4′-DDT)



WindWard environmental LLC

LWG Lower Willamette Group

0 500 1,000 1,500 Feet

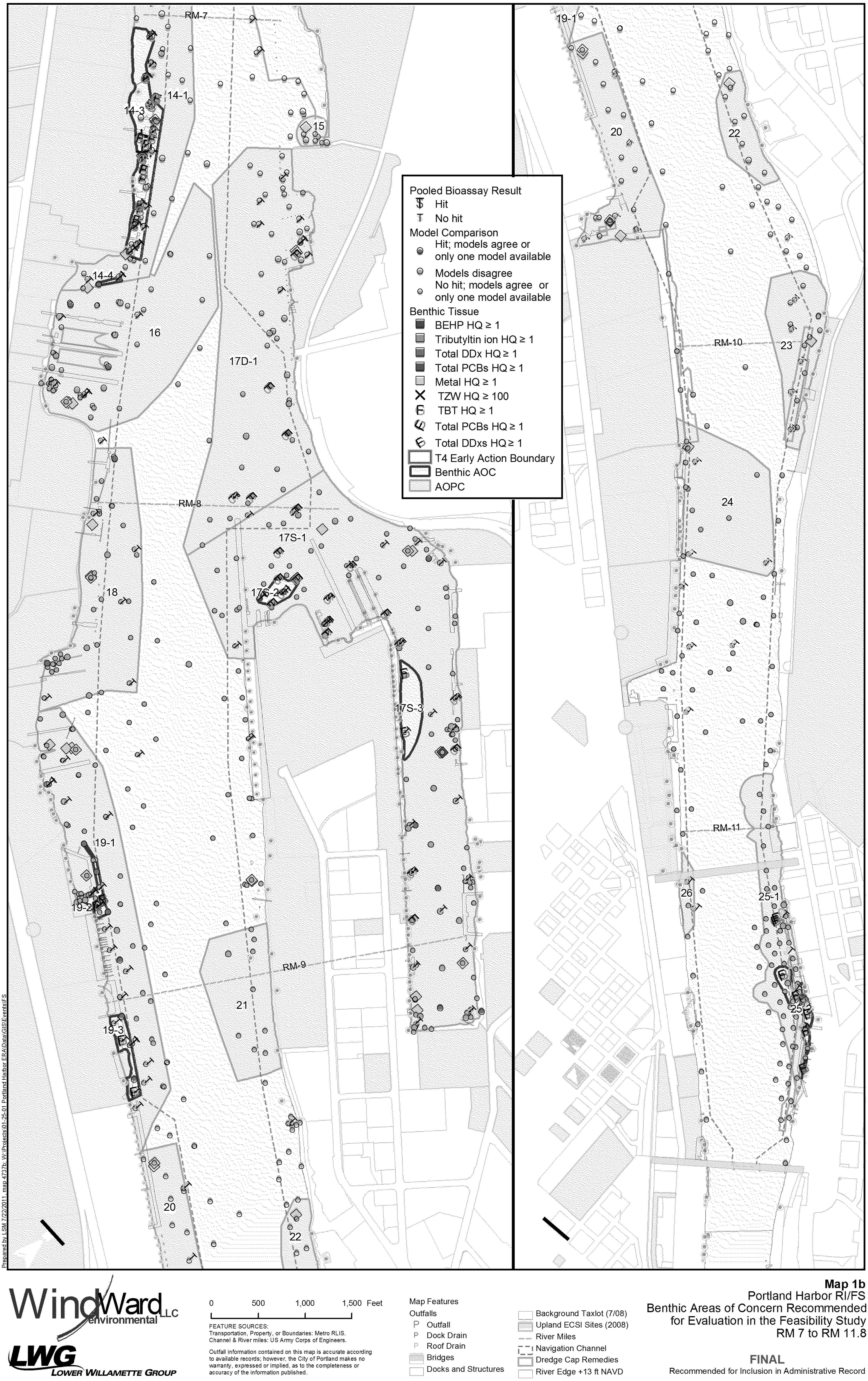
FEATURE SOURCES:
Transportation, Property, or Boundaries: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.

Outfall information contained on this map is accurate according to available records; however, the City of Portland makes no warranty, expressed or implied, as to the completeness or accuracy of the information published.

Map Features
Outfalls
- Outfall
- Dock Drain
- Roof Drain
- Bridges
- Docks and Structures
- Background Taxlot (7/08)
- Upland ECSI Sites (2008)
- River Miles
- Navigation Channel
- Dredge Cap Remedies
- River Edge +13 ft NAVD

Map 1a
Portland Harbor RI/FS
Benthic Areas of Concern Recommended for Evaluation in the Feasibility Study
RM 1.9 to RM 7

FINAL
Recommended for Inclusion in Administrative Record



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LWG LOWER WILLAMETTE GROUP

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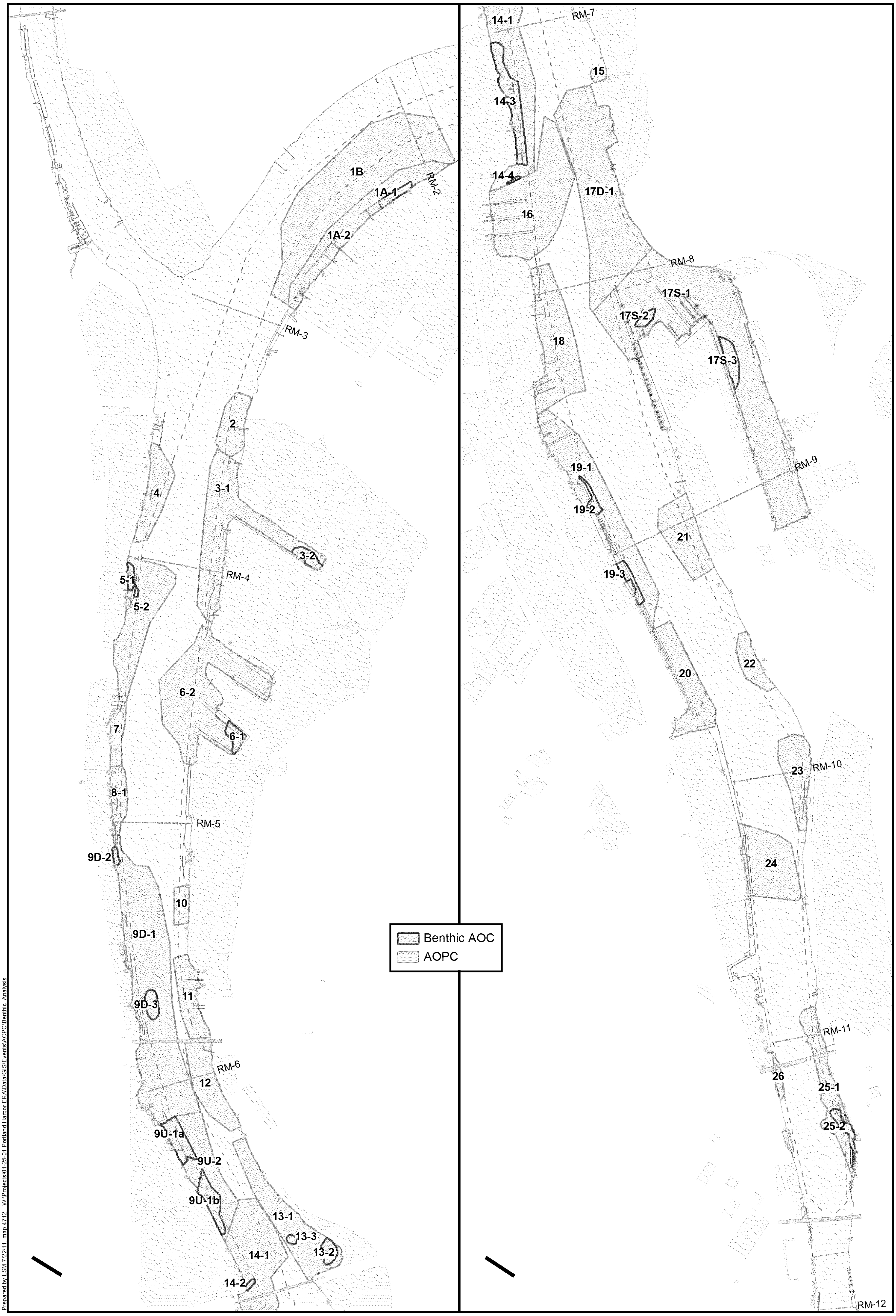
Map 1b
Portland Harbor RI/FS
Benthic Areas of Concern Recommended for Evaluation in the Feasibility Study
RM 7 to RM 11.8

FINAL
Recommended for Inclusion in Administrative Record



Prepared by LSM 7/22/11, map 4712 W:\Projects\01-25-01 Portland Harbor ERA\Data\GIS\Events\AOPCBenthic Analysis

Windward environmental LLC

LWG Lower Willamette Group

0 1,000 2,000 3,000 Feet

FEATURE SOURCES:
Transportation, Property, or Boundaries: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.

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P Outfall
P Dock
5 Roof
Bridge
Dock or Structure
Upland Site (2008)
River Mile
Navigation Channel
River or Slough

Map 2
Benthic Areas of Concern Recommended for Evaluation in the Feasibility Study
Portland Harbor RI/FS

FINAL
Recommended for Inclusion in Administrative Record